LECTURES

ON

ELECTRICITY.

BY

G. C. MORGAN.

VOL. I.

NORWICH:

PRINTED BY J. MARCH,

and sold by

J. JOHNSON, ST. PAUL'S CHURCH-YARD, LONDON.

1794.

Price 10s. 6d.

BRITISH MUSEUM

INTRODUCTORY

LECTURE.

LABOUR and patience, and an ardent devotion of the whole mind to the object of its purſuit, are the eſſential properties of thoſe who ſucceſsfully attempt either to learn or to improve a ſcience. When we enter, therefore, upon the ſtudy or inveſtigation of any particular branch of knowledge, it ſhould be our firſt care to

examine whether we poſſeſs the properties I have mentioned, and to diſcover the peculiar dangers to which we may be expoſed, of having them either diminiſhed, or miſapplied, or ſubdued, in our intended progreſs. If we adopt this mode of preparation in the preſent inſtance, we ſhall certainly diſcover, that the moſt common ſources of difficulty, of ſeduction, and waſte of power, in every other track of philoſophy, will infeſt and obſtruct the path of the electrician.

Wherever Nature urges

man to advance, while his reaſon is yet feeble, ſhe has kindly ordered the force of paſſion to aſſiſt and to propel. —From the tendencies of this force, proceed our dangers. In its brutal blindneſs, it is apt to ſtumble upon errors; and in its readineſs to be impreſſed and intereſted by firſt appearances, it is ever expoſed to the ſtruggles of obſtinacy, and the conflicts of ſelfiſhneſs; and in either of theſe caſes, the toil that overcomes is arduous and ſlow in its progreſs, and the neceſſary patience of thought takes place only

when much time and much labour have been ſquandered.

Electricity is in its infantine ſtate. Its language is imperfect and obſcure. Its appearances are moſt frequently diſplayed to amuſe the ſenſes, or to aſtoniſh the ignorant. The empiric or the itinerant only obtrude it upon the eyes of the world, and it is known by philoſophers only as a curious detail of facts, inſulated by very peculiar properties, and confuſed, owing to a want of arrangement or reference to

general principles. In ſhort, electricity is conſidered as deſtitute of all ſtimulants, either to provoke our vanity, or to inflame our ambition. For this reaſon, it is rarely made an object of eager and complete attention, or of that perſevering activity by which alone it can riſe to its proper conſequence and maturity.

It is to be regretted, that in rearing our minds towards perfection, we ſhould ever regard any motives but ſuch as are purely rational.

The clear eye of Reaſon views all parts of nature with equal intereſt, and inſpires us with the ſame plenitude of enthuſiaſm, whatever object we may follow in the immenſity of ſurrounding wonders. In caſe you were thus intellectual, every effort to keep your paſſions from obtruding upon your aſſiduity would be unneceſſary, and introducing philoſophy to you, as philoſophers, we ſhould lay aſide all previous advice and recommendation.——But allowing that you muſt be impaſſioned before you are properly induſtrious, and patient

and perſevering, I would wiſh to convince you that thoſe peculiarities of electricity, which have hitherto depreſſed and chilled the ardour of enquiry, ought rationally to have a contrary effect.

Is not the vanity of excelling more likely to be gratified where the names of your predeceſſors are few and obſcure, than amongſt thoſe who have been ſelected by public applauſe from the bright catalogues of improving centuries? Muſt not the pride of new diſcoverers enjoy more ample and more

frequent opportunities where the treaſures of nature are unexplored, than amongſt objects which have been ranſacked by the induſtry and emulation of ſucceſſive ages? How many years muſt you toil before you have traced out the ſteps already impreſſed by the great Newton? How little the probability of fluſhing up in the field, he has ranged through, one object which eſcaped his penetration? and how much leſs the probability, that its magnitude, when brought forward, will divert that attention which is already fixed

by the accumulation of his ſtupendous diſcoveries? In ſhort, if you are impelled by the deſires of *animal* nature, you will certainly ruſh into the courſe that is the leaſt known; and the ardour of your purſuit will not only be directed, but increaſed, by the obſcurity of its object.

Let me, however, hope that your reſolutions are already determined to ſeek no pleaſure from philoſophy, but thoſe of the mind; to obey no motive, but that which is rational; and to indulge no views, but thoſe

of enlightening the world by the improvement of your own faculties.

If this be the caſe, you will find that electricity is moſt amply inveſted with *powers* to anſwer all the great purpoſes to which you may aſpire. It poſſeſſes every property which can make knowledge intereſting to the human mind. The power, whoſe laws, whoſe relations, and whoſe effects it inveſtigates, is already proved to be one of the moſt extenſive in nature. There is ſcarcely any ſcience, whoſe light may not

be increaſed by it. Many are the arts in ſocial life to which it will communicate new powers, and many are the myſterious circumſtances in the hiſtory of nature and mankind which it developes, and clearly explains. But to impreſs you with proper ideas of theſe advantages, let us amplify on each ſeparately.

1ſt, We have already diſcovered the electric fluid to be the cauſe of thunder, meteors, the northern lights, and of many other appearances in the atmoſphere. We

cannot ſuppoſe (without a total diſregard to the common proceedings of nature) that a power, producing ſuch great effects, ſhould not extend to other objects without number, of equal importance in the general ſyſtem.

When that influence, by which a ſtone falls to the ground, was followed to the extent of its connexion with all the phœnomena of the tides, the complicate motions of the moon, and the remote circumvolutions of the ſeveral planets, if our progreſs had *then* terminated, our knowledge

of the gravitating power muſt have been confined and partial indeed, compared with that which ſtill remained to be unfolded; an infinite diſtance would have removed us from the height whence our preſent ſurveys are taken; we ſhould never have reached that extreme point where its ſway decides the return of two hundred vaſt worlds, which, with a velocity that mocks our comprehenſion, had fled from our neighbouring ſkies, in one direction, for three hundred ſucceſſive years. We ſhould never have penetrated the maſs of

this world, and the ſurrounding planets, ſo as to meaſure their varying attractions and ſolidities; nor ſhould we have ſeen the ſtupendous ſun in its greateſt glories, as a central world, ſurpaſſing in bulk and conſequence a million of ſuch as we inhabit; — much leſs ſhould we have ſurveyed the ſurrounding univerſe as a plenitude of ſyſtems, each of whoſe component parts are formed of all that is great in the united maſs of our ſun and its attendant worlds, and yet theſe parts are more numerous than the drops that form the vaſt Atlantic.

In ſhort, *wherever* we ſtopped in our purſuit of the gravitating influence, by aſcending, for thouſands of years, from one combination of wonders to another, *there* we ſhould have found ourſelves on the entrance only of its boundleſs activity. But the power of gravity and the electric fluid are alike the agents of the ſame wiſe Omnipotence, and we may reſt aſſured that their characters are ſimilar, and that our firſt enquiries, however ſucceſsful in the diſplay of their great operations, afford but faint, and confined and partial views

of what future inveſtigation may unfold before the eyes of philoſophy.

2dly, I have obſerved that the light of other ſciences may be increaſed or brightened by that of electricity. Its preſent connexion with ſome of them is merely that of conjecture and extravagance. In aſtronomy, it has been employed to account for the tails of comets; and the motions of theſe bodies have been ignorantly ſuppoſed incapable of explanation, without recourſe to its agency. In navigation, it

was expected to have worked great marvels, by furniſhing a magnet that would turn towards the Pole, without any variation. But, alas! this imaginary attainment appeared and vaniſhed with equal rapidity.

It is rather extraordinary that the electric fluid has not yet been thought of as capable of any connexion with mechanics. In a ſcience, the object of whoſe ſkill is the commencement, the increaſe, and the management of force, it is ſurely reaſonable to expect that a power may be

highly advantageous, which acts with unparalleled velocity, and which overcomes the moſt obſtinate reſiſtance.

Should ſome genius hereafter diſcover the method of employing Berthollet's new gun-powder with ſafety, perhaps this improvement in gunnery may owe its ſucceſs to the poſſibility of firing the dangerous ingredient, at a great diſtance, by the aid of the electric fluid.

Much has been attempted and profeſſed by electrical empirics, in the art of medicine;

but hitherto electricity has been chiefly employed as the inſtrument of quackery and impoſture. A few ſcientific profeſſors have tried its influence where the idea of doing no harm, and the deſpair of doing much good, has diſpoſed them to try any thing. There are certainly ſome ſtriking caſes, in which it has, ſeemingly, removed the moſt obſtinate obſtructions. But that ſkill is unknown, which is to develope its influence on the various parts of our organization, or which can anſwer for its effects in ſpecific caſes, ſo as to render the ap-

plication of it either ſafe or prudent.

In chemiſtry, much has been done by its union with electricity; but much more may be rationally expected. The properties of all fluids and ſolids are found to have been changed, when previouſly expoſed to the action of the electric fluid. It ſeparates the component parts of thoſe ſubſtances on which the ſtrongeſt fire of a reverberatory has no effect, and it is capable of being applied with accuracy and eaſe, where no other cauſe of change is ap-

plicable. In this connexion, however, our greateſt deſiderata are certain improvements in our apparatus. What we have, is complicate and troubleſome, and adapted to very few purpoſes, and a great deal of invention muſt become active before the poſſible rapidity of our progreſs can take place. In theſe Lectures I ſhall preſent you with ſeveral inſtruments, which have been employed by myſelf for this purpoſe; and I ſhall endeavour to place your minds in ſuch a train of thought as may lead you to the diſcovery of others, much

more commodious when uſed, and much more extenſive in their application.

Not more ſtimulating to the ardour of purſuit, is the proſpect opened by the connexion of chemiſtry with electricity, than that of the ſame ſcience with natural hiſtory. By the light emitted from this colliſion, we have already explained one of the moſt extraordinary appearances in the animal ſyſtem. The torpedo and gymnotus have been diſcovered to arreſt their prey at a diſtance, to benumb the moſt powerful energies of

life, and inſtantaneouſly to inflict death upon creatures far ſurpaſſing themſelves in ſtrength and velocity; by collecting the force of thunder, with a frequency adequate to their own wants; by darting it in all the directions in which eſcape is tried by the conſternation of their prey; and, finally, by reſiding in a medium, to every part of which the fire and fury of their lightning is commanded forth at pleaſure.

Provided Signor Galvani be right, the knowledge of

the electric fluid is leading us rapidly into a full inveſtigation of the nervous influence, and of all the myſteries connected with the ſenſations and motions of animal life.

To the previous advantages, derived from the union of electricity and natural hiſtory, ſeveral theoriſts have added the diſcoveries which are to proceed from the influence of the electric fluid on the growth and nouriſhment of vegetables. No deciſive experiments have yet proved that ſuch an influence

can take place. The fact is positively afferted by ſome, and is as poſitively denied by others. I ſhall hope to give you an account of what has been done on the ſubject. Indeed, I am rather diſpoſed to expect that the activity of the electric fluid may yet be very beneficial in this part of natural hiſtory.

The power it poſſeſſes, of dilating every circulating veſſel, of irritating whatever is capable of irritability, and of accelerating the motion of animal and vegetable juices in the minuteſt channels, af-

fords a ſtrong preſumption that it may haſten, not only the growth of plants, but add much to their ſize, and produce ſeveral extraordinary changes in their internal properties and their external appearance. There are ſeveral deſiderata which delay our progreſs in this buſineſs. We have not diſcovered an eaſy and cheap method of keeping up a conſtant current of the electric fluid; nor do we know how to convey it in a ſufficient abundance thro' all the parts of the ſame plant at the ſame inſtant of time.

3dly, Any agent, which alarms the ſenſes by a rare and anomalous diſplay of its operations in the viſible ſyſtem of nature, is to man, while groping in the night of ignorance, a moſt formidable tyrant. Horrors attend its appearance, and the general fear it calls forth is pregnant with calamities of long permanence, and of tremendous magnitude and extent. The hour of its ſway, is that of torture to millions, and, in the ſucceeding hours of timidity and depreſſion, new powers come into action, far more terrible

and deſtructive than itſelf. The general maſs of ignorance is, each time of its appearance, enlarged and condenſed, and the reign of ſuperſtition is confirmed and darkened. It arms the ruling prieſthood with the dagger; it clothes them with bloody robes, and gluts them, hungry in their demands of ſacrifice, for the angry god whom they repreſent, with the firſt-born of every kind.

The terrors, under which it ſubjects the quaking multitude, are equally mercileſs to the flocks of the field, and

to the moſt helpleſs of human innocents. It arms whole legions of tyrants, which tyrants collect hordes of voracious janiſſaries, who unite in one confederacy to plunder, to enſlave, to corrupt, and, finally, to exterminate thoſe whom they at firſt frightened and deceived.

In all ages the thunder of heaven, by the diſplay of its own peculiar greatneſs, and by co-operating with other awful agents in nature, has contributed moſt powerfully to promote the cauſe of impoſture and tyranny. The

roar, by which it ſhakes earth and ſky; the blaze, which it ſpreads in one inſtant thro' the whole concavity of heaven; the impetuoſity with which it precipitates palaces, caſtles and temples into ruins; the impotence of the mightieſt amongſt viſible beings, when aſſailed by its fury: theſe tremendous conſequences of its own immediate agency are accompanied by others, reſulting from that agitation of elements which it has produced. It inundates the earth with a deluge. It lets looſe the tempeſtuous ſtorm from the black cloud in which it

is ſuppoſed to reſide; and the concuſſions of earthquakes and volcanos, are frequently amongſt its attendant horrors.

All the preceding are circumſtances whoſe powers are fully adequate to the proſtration of every ignorant mind, at the feet of blaſphemous fraud and uſurpation. We conſequently find that the ſupreme god of the Greeks was the god of thunder, and that their deſcendants ſecured the obedience of plebeians and ſlaves, by cheriſhing the ſame ſuperſtition, and by con-

triving new rules and ceremonies, new cruelties and abſurdities, to renovate the general panic, whenever awakened by the recent devaſtations of a thunder-ſtorm.

By the ſcience of electricity, however, the future poſſibility may be exterminated, of renewing theſe frauds or blaſpheming the benevolence of nature, by perverting the ſublime language of its operations to the purpoſes of human wickedneſs and the promotion of human miſery. It has enabled the moſt common artificer to avert every

danger attending a thunder-ſtorm, and conſequently to ſilence every apprehenſion. It teaches the vulgar mind to ſmile at a thouſand religious ceremonies, before the reverence of whoſe age, and the dignity of whoſe prieſts, the oſtentation of modern hierarchies dwindles into meanneſs and mummery.

When the domes or ſpires of our moſt ſacred temples are cracked by lightning, inſtead of trembling before an angry God, and invoking his preſumptuous ſervants to light his altars, and maſſacre

his creatures, we have only to lament that the blackſmith had not been employed, and that his iron rods were not erected. If thick clouds are gathered together in the weſt, and, amidſt the noon of day, bring on the darkneſs of night, the approaching appearance is ſurveyed as the probable ſource of amuſement, and the philoſopher, awakened from contemplation into buſineſs by the ſound of his bell, conducts the lightning into his habitation, or commands it to any diſtance preſcribed by his own pleaſure and convenience.

If you were to extend the preceding compariſon of the preſent and paſt ſtate of man, in its relation to one of the grandeſt agents in nature; if you were ſtill further to inveſtigate the important changes which have reſulted from the diſcoveries of electricity, you would, I think, look up to it as entitled to the higheſt eſtimation of philoſophers:—would you not likewiſe acknowledge that no tyrannicidal hero had ever proved more beneficial to his ſpecies, than that republican, who, when he had diſarmed the clouds of their fury, armed his coun-

trymen on the very ſame ſpot in the cauſe of freedom and humanity ?

On the banks of the Dirce, Greece, in her moſt civilized hour,—Greece, diſplaying to the wondering world a conſtellation of the moſt ſplendid luminaries that ever adorned and enlightened the human ſpecies, celebrated with hymns and dances the birth of that benefactor, who firſt preſſed the grape, fermented its juice, and poured its joys into the boſom of man.

When the golden times

come, in which poſterity will look back to the age of tyrants, of their prieſts, and the whole hoſt of their janiſſaries, as the dark and barbarous age of mankind ſtruggling with monſters and wild beaſts, will not the higher orders of beings, whoſe intellects brighten the glorious day in which they live, expreſs a gratitude ſimilar to what I mentioned, on the banks of the Delaware?— Let poetry be raiſed to what it was in Athens, the perfection of philoſophy. Let every art reach the fulleſt maturity which reaſon can give it,

when cultivated by the leiſure and education of myriads improving thro' ſucceſſive centuries; and amongſt the higheſt objects of its praiſe, will not eminence belong to the example and intellectual greatneſs of Benjamin Franklin, who, when he had wrenched the thunderbolt from the graſp of tyranny and fraud, enrolled himſelf amongſt the heroes and patriots of his country, chaſed away the minions and mercenaries of oppreſſion, and amongſt the ruins accumulated by deſpotiſm in the fury of its dying hour,

eſtabliſhed the firſt free community that ever bleſt the eyes of men?

I have been amplifying, gentlemen, on the *obvious* utility of that ſcience, which it is your object ſoon to acquire; but I will repeat my wiſhes that the pure and elevated condition of your minds may render all ſuch amplification unneceſſary.—He that enters the path of knowledge, as he would that of commerce, or who begins his enterprize with ſpecifying the benefits he is to ſecure, will never make any conſiderable progreſs. He will

ſoon be arreſted by diſappointment, and will terminate a labour which does not provide him with what he particularly expected.

There is but one conſideration that bears ſway in the ſoul of a philoſopher. That truth ſtands alone which intereſts his deſires, and ſtimulates his active principles. He is convinced, that to follow nature is to follow the ſure road to boundleſs attainments: for its treaſures fill the univerſe; its means of gratification are not leſs various than thoſe ſcenes and

objects by which it has diverſified, enriched, and adorned immenſity; and the wonders, by which it elevates the mind, and overwhelms it with tranſport, ſucceed each other in multitudinous combinations, not leſs numerous than the ſwarms of life in ſummer, nor leſs rapidly than the inſtants which form eternity. Nay, the paradiſe of a philoſopher, devoted to the ſtudy of nature, is not confined to earth, or ſea, or air; to the third or fourth heavens; but includes thoſe diſtant regions which the light of a day, that ſhone thouſands of years

ago, has not yet reached! He feels it every where; he enjoys it at all times. Its pleaſures burſt forth from every viſible object; they ſpring from the ground he treads upon. The atmoſphere teems with them. They are to be found in the maſs and in the loweſt depths of the ocean. They flouriſh in the deſert and amongſt precipices and rocks. They are preſent amongſt the horrors of volcanos and earthquakes; nor do they forſake the mind when looking forward to the deſtruction of worlds and their ſyſtems.

But in caſe the philoſopher wanted thoſe powers of beatific viſion which I have deſcribed; allowing that a cloud ſeparated him from thoſe views of the univerſe, by which ſcience raviſhes and enraptures the mind; allowing that all diſcovery had hitherto eluded his purſuit, and that his labours opened no other proſpect but that of aiding future attempts; he has ſtill to pride himſelf in the attainment of a moſt glorious reward.

Mental purſuit is a diſcipline that not only increaſes

the ſtrength we have, but creates new and greater energies in man. The faculties of the ſoul, like thoſe of the body, become gigantic and mighty, by exertion only: and what delicious conſciouſneſs equals that of a mind triumphing in its own vigour? ſatisfied with its own exertions, and fitted for thoſe more important circumſtances of action which may ſtill remain for it?

But does the ſcience, upon which we are entering, participate in that character of philoſophy, whoſe improving

powers I have juſt deſcribed? When I anſwer in the affirmative, I feel that I ſhall be juſtified by your future experience.

Electricity poſſeſſes much of what is admirably adapted to diſcipline the mind. Its new principles, though few, will admit of extenſive application; but that application will belong to thoſe only who can proceed patiently through a great deal of intricacy and embarraſſment. The appearances of electricity, likewiſe, are entangled with the effects of many diſ-

tinct cauſes. They require, therefore, much of that toil which ſeparates carefully, which combines judiciouſly, which ſelects with ſeverity, and then arranges with clearneſs and preciſion. Beſides, this ſcience demands the co-operation of the hands and the head, or the exerciſe of manual ſkill, united with a ready capacity of inventing and diverſifying the means of experience. The accumulation of electrical facts, moreover, is increaſing daily, and conſequently affords opportunities favourable to the retentive faculties of the

mind. The circumſtances of its experiments are connected by no general ſyſtem. They are, as it were, inſulated; and of courſe the remembrance of each minute difference requires a diſtinct exertion, and renders it very difficult to obtain ſuch a familiarity of acquaintance with the whole catalogue of its appearances as will enable you pertinently to bring them forward, either in evidence or explanation.

In ſhort, the ſcience of electricity is well formed for ſtrengthening the memory,

for invigorating its powers of aſſociation, and for habituating us to ſuch deliberate and multiplied pains as are neceſſary to complete the images or mental impreſſions which, with equal pains, we have previouſly eſtimated and ſelected.

Let your reſolutions then be formed to ſtudy electricity as a ſcience in all its tendencies, favourable to the general intereſt of knowledge, and to your own particular improvement; devote to it a portion of your moſt undivided attention; make it a

work of labour and patience, and if diſappointment or fatigue ſhould ſubdue you, determine either to reject it altogether, or to purſue it with ardour, with perſeverance, and all the beſt energies of your ſeveral faculties.

The directions which are appropriated to the ſtudy of electricity, as a diſtinct branch of ſcience, are of two kinds.

1ſt, There are directions which have a reference to your progreſs, while you receive the inſtructions of your tutor.

2dly, There are other directions by which you will be guided in your future endeavours to increaſe the ſtore of known facts, or to develope the unknown laws and principles of electricity.

1ſt, While you attend the preſent courſe of Lectures, endeavour to keep your eyes and your memories altogether unencumbered, ſo that you may perceive the order in which the ſeveral parts of the apparatus are united: you will thus be able to retrace with new force of impreſſion, and at the ſame time to cor-

rect thoſe ideas which I ſhall have previouſly endeavoured to communicate by verbal deſcription.

My plan of inſtructing is formed with a view to aid you in this method of improving yourſelves. I begin with deſcribing the ſimpleſt machinery, and the appearances immediately dependant on their operation. I proceed gradually with ſmall additions to the machinery already deſcribed, and with the facts reſulting from each ſeparate addition. After I have firſt deſcribed, I make

the experiments, ſo that each ſucceſſive appearance may anſwer to the order obſerved previouſly in the verbal deſcription. In conſequence of this method, the memory is aided by repetition, and what it has received by the ear, is rendered more permanent by the ſubſequent impreſſion of what is offered to the eye.

A moſt detrimental cuſtom belongs, I obſerve, to ſome pupils. They ſpend their whole time in looking at their papers, and in ſcribbling imperfectly, what they as imperfectly recollect of the lec-

turer's expreſſions. Their buſineſs conſequently becomes ſo very complicate, that to inſtruct them with any accuracy, or to any extent, is altogether impoſſible. At one and the ſame inſtant, they have to write, to ſee, to make up the expreſſions they remember imperfectly, and to diſpoſe of what is unintelligible in the tutor's language, who, lecturing extempore, if he does it properly, muſt be now and then at a loſs in attempting to change the words and order of his ſentences, whenever he finds, from the looks of his pupils,

that they do not comprehend him.

When the lecture is over, then is your moſt important care to commence. You ſhould, as ſoon as poſſible, endeavour to copy upon paper, what you have taken into your memories; for, reſt aſſured, that if you have learned any thing well, you will be able to write it down. A ſure evidence that you have learned nothing, is the inability of expreſſing the ideas which you have received. Beſides, from what you write, you will know both the quantity and

the quality of what you have gained; and the one may be increaſed, and the other corrected, by having recourſe to your tutor, or to thoſe books which are written on the ſubject of your enquiry, or by endeavouring, on the apparatus, to repeat his experiments, and to recover the circumſtances you had forgotten.—In experimental philoſophy, however, it is of the utmoſt importance, that you ſhould attend the ſame lectures twice; for by this means, when you retire to examine the ſtores you have collected, the fruits of your ſecond at-

tention will always mature thoſe of the firſt.

2dly, Should your love of ſcience gain ſuch ſtrength, during the courſe of your inſtruction, that you are determined to purſue it, you will then have new circumſtances to regard. It will be neceſſary that you ſhould provide yourſelves with a proper apparatus, and patiently to toil through the whole of that diſcipline, which is requiſite to the formation of a dextrous experimentaliſt.

In theſe Lectures I ſhall

deſcribe, very minutely, the proper inſtruments of the ſcience. But when you know the beſt of theſe, you ſhould likewiſe know that there are two ways of procuring them. You muſt either have recourſe to thoſe who live by making them, or you muſt work for yourſelves. The former method is expenſive, and takes away from electricity one of its moſt advantageous ſingularities, that of being cheaply purſued and cultivated. Beſides, this method is the ſloweſt poſſible; for he who makes experiments well, muſt vary them a thouſand dif-

ferent ways; and great is the loſs of time and labour, great the waſte of power, that muſt harraſs thoſe who have firſt to direct, and then to wait upon the conveniences of a common inſtrument-maker.

If you ſhould reſolve to work for yourſelves, few utenſils are neceſſary. The firſt and moſt important is a turner's lathe; by which you may furniſh yourſelves with balls, caps and the pedeſtals of your ſtands. Indeed, there is ſcarcely one diverſity of means in electricity, with

which you may not be provided, when you have acquired a moderate ſhare of ſkill in uſing this machine.

A blow-pipe is neceſſary for bending tubes, and for opening and cloſing ſuch as are of conſiderable diameter. The art of filing with tolerable truth; of covering wood and glaſs with tin foil, ſo as to leave no points, edges, or wrinkles; together with ſome little dexterity in the inferior employments of chemiſtry: theſe arts, I ſay, in conjunction with that of turning and of blowing glaſs, comprizes

the whole mechanical knowledge that is wanted by an electrician. In the track of your purſuit, a multitude of unknown neceſſities muſt ariſe: but theſe, when ſupplied or conquered, will add to the intereſt of your employments, and the pleaſures of your ſucceſs.

In the Lectures you are now to hear, you can expect that information only which relates to the moſt important parts of the ſcience. You may abundantly increaſe your ſtore of electrical facts, by

directing your future attention to

Dr. Franklin's Letters on Electricity.

Dr. Prieſtley's Hiſtory of the Science.

Mr. Cavalio's Treatiſe, together with his ſeveral papers on the ſubject, to be found in the Philoſophical Tranſactions.

A ſmall pamphlet containing curious particulars relating to poſitive and negative electricity; by Dr. Milner, of Maidſtone, in Kent.

Mr. Brook's "Miſcellaneous Experiments," &c.

Mr. Bennet's "New Experiments;" and

Mr. Reed's "Summary View of the Spontaneous Electricity of the Earth and Atmoſphere.

There is little in the Philoſophical Tranſactions, which Dr. Prieſtley has not condenſed in his Hiſtory.

Foreigners attend much more to chemiſtry than electricity; in their journals, therefore, you will diſcover nothing to reward the toil of ranſacking them, if you except Volta's papers in the "Scelte D'Opuſcule."

A

SYLLABUS

OF THE

FOLLOWING LECTURES.

	PAGE
THE general cauſe of electrical appearances - -	1
The effects peculiar to the different degrees of its operation -	2
Circumſtances which affect its operation - - -	3 4
Different characters of its effects, or the diſtinction of poſitive and negative electricity - - -	5 6
Method of determining them -	7 10
The duration of electrical effects	11
The poſſibility of exciting them in bodies of all dimenſions -	12
Their extent	
The law of electrical influence -	

Page

Theory to account for the electrical appearances juſt deſcribed

The corporeal nature of the cauſe of electricity - - 17

The neceſſity of its being ſubject to an attractive force, and in its turn of its exerciſing it - 19

The change of this force, in conſequence of the contact of different bodies, adequate to all the appearances dependant on friction 20 26

Facts which ſeem to confirm the theory 27 30

The only difference between preſſure and friction - - 30 32

Immediate application of the theory to the elucidation of deſcribed facts 32 35

The appearances dependant upon the collection and motion of the electric fluid, when produced by friction 37

Apparatus neceſſary to ſhew theſe appearances - - 38

Page

The ſound of the electric ſpark 40
Thoſe varieties of the ſpark which depend upon the various forms and dimenſions of the body around which the fluid is collected 42
The figure of the ſpark - 48
The length of the ſpark - 51
The force of the ſpark - 60
The light of the ſpark - 63

Appearances attending the accumulation of the electric fluid upon glaſs, and other electrics - 67
Deſcription of the requiſite apparatus, and a general view of the appearances 67 71
Varieties in the appearances which proceed from the poſſible varieties of the glaſs veſſel - 71
- - - - - - - of the coating 75
- - of the uncoated part of the glaſs 77
- - - - of the diſcharging-rod 83
Theoretical view of the preceding facts taken from three leading principles 85 97

Page

1. The corporeal nature of the electric fluid - - 85 97
2. The union of the electric fluid with other bodies dependant upon an attractive force - - 85 97
3. A certain quantity only of the electric fluid belongs to bodies in given circumſtances - - 85 97

An application of the preceding principles to the accumulation of the fluid on the ſurface of electrics, and to its paſſage thro' conducting bodies 98 102

The theory applied

1ſt, To the correction of the language uſed by electricians concerning the different ſtates of the ſame body 102

2d, To the elucidation of the ſeveral progreſſive changes which take place when a body is charged 108

No neceſſity for a repulſive power 109

Dr. Franklin's theory examined 112 116

3d, To the appearances of the diſcharging-rod - 116

4th, To thoſe of the metallic coating 118

Page

5th, To the analogy between the appearances of charged air, and of other charged electrics - 119
6th, To the breaking of the glaſs by the charge - - 123

The ELECTROPHORUS—a deſcription of its conſtruction - 147
The method of uſing it - 148
The effects of the electrophorus 149
Mr. Bewley's explanation 150
Its difference from a common electrical machine - - 153 157
An application of principles already explained, to the illuſtration of the electrophorus - 157 163

The INSULATED ELECTROPHORUS deſcribed - - 163
The various appearances attending the uſe of it - - 163 174
Explanation of the preceding appearances - - 174 181

Page

The DOUBLER, a deſcription of it 181
Illuſtration of it by Mr. Bennet 184
The preceding illuſtration examined 185 192
The doubler ſhewn to be an electrophorus - - 193 197
The MOVEABLE DOUBLER, a deſcription of it - 198 199
An account of its effects - 200 203
Mr. Bennet's explanation 204 205
The preceding explanation examined 206 207
Mr. Read's theory examined 208

ELECTRICAL LIGHT - 212
Arguments and facts for the following propoſitions relating to it:
1ſt, There is no fluid or ſolid body in its paſſage through which the electric fluid may not be made luminous 213
2d, The difficulty of making any quantity of the electrical fluid luminous in any body, increaſes as the conducting power of that body increaſes - - 216

Page

3d, The eaſe with which the electric fluid is rendered luminous in any particular body, is increaſed by increaſing the rarity of that body 218

4th, The brilliancy or ſplendour of the electric fluid, in its paſſage through any body, is always increaſed by leſſening the dimenſions of that body 223

5th, In the appearances of electricity, as well as in thoſe of burning bodies, there are caſes in which all the rays of light do not eſcape; the moſt refrangible are thoſe which eſcape firſt or moſt eaſily - 228

6th, That the influence of different media on electrical light is analagous to their influence on ſolar light 230

Principles which account for the varieties of appearance belonging to the light of electricity:

1ſt, The attractive force which unites the conſtituent parts of different bodies muſt be altered by increaſing or diminiſhing the quantity of any particular conſtituent in the body 238 242

Page

2d, The attractive force, which unites the particles of light to any body, muſt be diminiſhed, or increaſed by an addition to its natural ſhare of the electric fluid - 244

VOL. II.

On the Conducting Powers of Bodies.

The principle on which the examination of theſe powers is founded 3

The neceſſary apparatus - 4 8

Lane's electrometer examined 9

Neceſſity of a diſcharging-rod 10

Its requiſite properties - 10 12

Deſcription of the diſcharging-rod 12 16

Inſtrument for giving the fluid its choice of two paſſages - 16 19

Inſtrument for meaſuring the conducting powers of bodies by the expanſion they cauſe - - 19 30

Page

The connexion of the conducting power with the terminations of the bodies which form the electric circuit.

1ſt, Varieties of the ſtriking diſtance, when the charge ſtrikes from one flat ſurface to another - 31

2d, From one point to another 32 39

3d, From a flat ſurface to a point 39 41

4th, From balls to points - 42 46

Obſervations on the preceding facts 47 49

An attempt to account for the varieties of the ſtriking diſtance, which depend on the terminations of conducting bodies - - 49 61

On the conducting power of water.

Additional apparatus for the purpoſe of determining this power - 62 66

The different reſiſtances made by columns of different dimenſions of water - - 67 70

Page

The comparative ſtriking diſtances when the electric fluid paſſes *luminouſly* through columns of different dimenſions - - 70 72

The conducting power of water determined by its expanſion during the paſſage of the fluid - 72 74

The ſame power examined by the reſidues of charges - 74 75

The ſame power determined by the paſſage of the fluid over thin lamina of water - - 75 77

The effect of the terminations of conducting wires in water directly the reverſe of what takes place in air 77 80

The effect of temperature on the conducting powers of water 80

Effect of the pulverized particles of non-conductors - - 82

Several facts explained by the aid of the preceding facts - 84 87

Directions for the further inveſtigation of this ſubject - 88 90

Conducting Power of Spirits of Wine.

	Page	
1ſt, The different reſiſtances made by columns of different dimenſions of this body - -	90	94
2d, The conducting power examined by conveying the charge over thin lamina of ſpirits of wine	94	
3d, The ſame power examined by the luminous ſtriking diſtance of the charge in columns of different dimenſions - -	94	
The ſame power examined by the reſidue of diſcharged jars -	95	
- - - - - - - - - by expanſion	97	
Obſervations on the preceding facts	97	99
The conducting power of vitriolic æther examined by the methods applied to the ſpirits of wine -	99	103

The non-conducting or reſiſting Power of Oils.

Precautions to be obſerved in making experiments on theſe bodies	104	106

Page

The power determined by the different breaking diſtances in columns of various dimenſions of different oils 106 110
Obſervations on the preceding facts 110 113

The non-conducting Powers of Airs.

Deſiderata by which the experiments were directed - 113 115
Facts relating to the ſtriking diſtance in common air - 115
- - - - in inflammable air - 116
- - - - in dephlogiſticated air 116
- - - - in nitrous air - - - 117
Facts relating to the expanſion of different airs by different charges 118 120
Directions how to proceed with the inveſtigation of this ſubject 121 123

Conducting Powers of the Acids.

Comparative ſtriking diſtances when the charge paſſed through vitriolic acid in capillary tubes - 126

Page

Comparative ſtriking diſtances of metal and the vitriolic acid in tubes of different diameters - 128

The *luminous* ſtriking diſtances in vitriolic acid in tubes of different diameters - - 128 129

Conducting power meaſured by expanſion - - 129

Its conducting power when ſpread over the ſurface of an electric 130

The effects of diluting the vitriolic acid on the conducting power 131

Reſiſting Powers of ſolid Non-conductors - - 133

Shell lac - - 135

Plate glaſs - - 135

Sulphur - - 136

Bees-wax - - 136

Obſervations - - 137 139

Reſiſting Powers of partial Non-conductors.

	Page	
Lignum vitæ - -	140	
Charcoal - -	141	147
Conducting power of charcoal compared with that of vitriolic acid	148	
Conducting powers of earths, alkalis, neutral ſalts, and of water ſaturated with them - -	149	
Signor Volta's opinion concerning the inſulation of partial non-conductors	151	
His experiments on the ſubject	152	
His *electrical paradoxes* examined and explained - -	153	
His opinion of condenſation controverted - -	159	160
The conducting powers of the metals	161	166
Influence of rarefaction on the conducting powers of fluids	167	
Mr. Morgan's experiment on a perfect vacuum - -	171	

Page

Theoretical explanation of the ſeveral facts which are previouſly deſcribed as related to the conducting powers of bodies - - 176 192

Explanation of the breaking of electrics by the paſſage of the charge 193

Application of electricity to the appearances of nature - 202

Conjectures concerning the cauſe of thunder, previous to the diſcoveries of Dr. Franklin - - 205

Preſumptive arguments for his theory of thunder - - 207

- - - - - - - His experiment 207 208

The ſeveral appearances of lightning explained, on the ſuppoſition that it is produced by the electric fluid - - 209

1ſt, The changes dependant on the motion of the clouds - 210

Page

2d, The explosion - 211
The opinion that it ever strikes into the earth as in a state opposite to that of the air, controverted 212 217
A more consistent explanation of the agency of the earth proposed 218 225
3d, The form of the flash 225 229
4th, The noise of the flash 229
5th, The colours of the flash 232
6th, The devastation of the flash 236
An explanation of the mode in which it fuses and tears bodies 237 241
Its peculiar effects on the human body 243 252
7th, The distances at which a thunder-cloud becomes dangerous 253
Methods of calculating the size of a thunder-cloud - 260
Lord Stanhope's theory of the returning stroke - - 267 282
Signs of approaching danger 283 286
Different methods of protection in different situations - 287 289
Best conductors for houses 290 300
- - - - - for ships - 300 302

Page

The origin or cauſes of natural electricity - - 303
The abſorption and precipitation of aqueous particles from the atmoſphere - - 304 306
The violence of ſtorms in different places correſpondent to the abſorption and ſudden precipitation of moiſture - - 307
Tropical ſtorms - 307 308
The electrical appearances of a volcano - - 308
The ſtorms peculiar to all the regions bounding the ſandy deſerts of Africa 309 312
The different caſes of precipitation applied to the different appearances of electricity - - 313
1ſt, When a colder air is mixed with a hotter - - 313
Applied to the daily changes of electricity perceptible in the atmoſphere 313 314
Applied to the ſudden collection of thunder-clouds - 315
Applied to the violence of tropical ſtorms - - 316

Page

Applied to the quick ſucceſſion of flaſhes that is obſervable in ſome ſtorms - - 317 322

2dly, When air of a hotter comes in contact with earth of a colder temperature - - 322

Applied to the electrical appearances of high grounds - 323 325

3dly, When the ſun's heating influence is ſuddenly interrupted 326

The electricity of dews - 327 329

The general commencement of a ſtorm as the night approaches 330

The effects of winds on the electricity of the atmoſphere - 333

NORTHERN LIGHTS - 334

A general view of the theories received antecedent to the diſcoveries of electricity - - 334 336

Reaſons for conſidering them as electrical appearances - 336 339

Peculiarities of the northern lights accounted for - - 340

Page

1ſt, Their northernly appearance 340 345
2d, The varieties of their colours 345 346
3d, Their undulations - 347 349
METEORS - - 350
Falling ſtars proved to be electrical appearances - - 350 354
Dr. Blagden's account of meteors 355 357
His reaſons for conſidering the meteors he deſcribes as electrical phœnomena - - 357 361
Objections to Dr. Blagden's hypotheſis - - 361 364
EARTHQUAKES - 365
Dr. Stukeley's theory examined 365 372
Beccaria's theory examined 372 375
Objections to the preceding application of the electric influence 376 382

Relation of the electric fluid to vegetation - - 383
A ſhort hiſtory of what has been done on this ſubject - 383 385

Page

Dr. Ingenhouſz's ſcepticiſm 385 386
Mr. Duvernier's reprehenſion of it 386
Dr. Ingenhouſz's reply - 387 390
Dr. Carmoy's experiments, in oppoſition to Dr. Ingenhouſz 391
Dr. Carmoy ſupported by the Abbe d'Ormoy - - 391 393
Reaſons for ſuppoſing Dr. Ingenhouſz to be right - 394 397

Relation of the electric fluid to animal life - - 394
1ſt, Its influence on the propagation of life - - 398 401
2d, Its activity in the animal œconomy - - 401
Mr. Walſh's diſcovery - 402
Mr. Henly's doubts - 403
Mr. Cavendiſh's refutation of objections - - 403
The various degrees of ſtrength belonging to the ſhocks of the torpedo and gymnotus - - 404 405

Page

The circumſtances which ſeem to have determined nature in furniſhing their organs to the electrical fiſhes 407

A probable view of the method in which the electrical fiſhes accumulate and diſcharge - 409 414

The effects which ariſe from their peculiar mode of operation 414 416

Signor Galvani's diſcovery

Preliminary obſervations 418 421

The experiments of Signor Galvani, and of others who have purſued the ſame ſubject - - 422 423

An attempt to account for the preceding facts by principles previouſly explained in theſe Lectures 425 438

ELECTRICAL APPARATUS.

Reaſons for preferring glaſs to all other electrics for excitation 439

Reaſons for preferring the cylindrical form - - 440 443

Page

Precautions to be uſed in chuſing cylinders - - 444
The relative dimenſions of the moſt convenient cylinders - 445
The beſt caps - - 445 446
Directions for the conſtruction of the handle - - 447
Inſulations of the cylinder 447
The cuſhion - - 447 448
The ſilk - - 448
Support of the cuſhion - 449
Dimenſions and materials of the beſt conductor - - 449
Method of fixing the points 450
Recipe for the beſt amalgam 450 451
Directions for working the machine 451 452
Two methods of applying the fluid when collected - 453
1ſt, Immediately from the conductor 454
2d, By means of the Leyden phial 455
Requiſites in the conſtruction of a battery - - 457
Directions for the conſtruction of a battery - - 459 461
Diſcharging-rod - 461

Page

Mr. Brooke's electrometer 462
Mr. Bennet's electroſcope 463
Mr. Cavallo's electroſcope 464
Conductors for aerial electricity 466 467
Objection to the uſe of a torch 468
Chemico electrical apparatus 469 470
- - - - for various kinds of air 471
- - - - for water, ſpirits of wine, and oil - 473
- - - - for the acids - 474
- - - - for ſolids - 475

LECTURES

ON

ELECTRICITY.

ALL thoſe electrical phœnomena, which depend on the operations of art, are the conſequence of friction. By rubbing a piece of dry ſilk, of hair, worſted, leather, or ſkin, againſt a ſurface of glaſs, of ſealing-wax, roſin, amber, or of any one body in a long catalogue of ſilicious and reſinous ſubſtances, which might be enu-

merated, a power is communicated to the rubbed ſurface of attracting ſuch light bodies as the down of feathers, the floating particles of duſt, and the threads of linen and ſilk, if delicately ſuſpended.

If the rubbed ſurface be equal to that of a few inches only, we may perceive a whizzing, ſnapping noiſe, when the finger is applied; the appearance of light, if the affected ſurface be carried into the dark; and a creeping ſenſation, if it be applied to the ſkin.

The operation of rubbing, when attended with the effects which I have now deſcribed, is called the *excitation of a body*, and all bodies,

which are capable of this excitation, are called *electrics*.

Many are the peculiarities immediately connected with the act of excitation: theſe I would now recommend to your attention.

I. If the leaſt moiſture or dirt defile the ſurface of your electric, the degree of excitation will be very much diminiſhed: this cannot be ſaid of greaſe and other inflammable bodies. The effects of excitation may be increaſed by oil very moderately uſed; and you will hereafter ſee that an amalgam of metals and ſome fat ſubſtances is daily uſed for the ſame purpoſe.

II. Different ſubſtances are differently affected by this ope-

ration. The diverſity is beſt explained by a fact.

FIG. I.

AB is a glaſs ſtem, not leſs than ſix inches in height: Bc is a wooden pedeſtal, into which the glaſs is fixed; AD is a wire, to whoſe blunt termination are annexed two very fine ſilken threads, e, f, whoſe length is not leſs than four inches. If a poliſhed ſurface of glaſs, when excited, be brought near the threads, e, f, they will ſeparate into the ſituation of g and h. But if, when thus circumſtanced, you approach them with an excited ſurface of wax, roſin, *unpo-*

liſhed glaſs, &c. the threads g and h cloſe again into the ſituation of e, f. Vice verſa, If the excited wax or roſin, or unpoliſhed glaſs, be firſt applied to the threads, a ſeparation will take place, and the ſubſequent application of the excited glaſs will bring them together.

It is of the greateſt importance to remember, that every excited ſurface, which cloſes the threads, when previouſly ſeparated by *poliſhed* glaſs, is ſaid to be *negatively excited;* and that every ſurface which, on application, produces no effect, or ſeparates them ſtill further, is ſaid to be *poſitively excited.* Vice verſa, If the threads be ſeparated by *excited ſealing-*

wax, whatever ſurface then cloſes them, is, *charged poſitively*; and whatever ſurface ſeparates them wider, or produces no change, is, *charged negatively*.

The ability of determining theſe different ſtates includes a very great part of its operations in the preſent ſtate of the ſcience.---- Electricians, therefore, have invented a variety of inſtruments, from the idea that ſome of them utter the ſame language much more expreſſively and diſtinctly than others.

In very delicate experiments, one thread has been ſubſtituted by electricians, in the place of the two threads, e, f, Fig. I. To

render it ſuſceptible of the leaſt influence, they have uſed the fineſt drawn filament which could be gained from the ſilk, as it immediately proceeded from the worm. This thread, when previouſly affected by an excited ſurface in one ſtate, on the application of a ſurface in a different ſtate, would be inſtantly attracted. Balls made of the pith of elder have been affixed by ſeveral electricians to the extremities of the threads.

But the uſe of every contrivance of this kind has been wholly ſuperſeded by a very late invention, which I ſhall now deſcribe.

AB, Fig. II. is a piece of braſs paſſing through the neck of the

glaſs veſſel, A, F, C, D. At the extremity of the braſs, B, are faſtened two ſtrips of gold leaf, m and n. The bottom of the veſſel, Pg, has been uſually made of ſome metallic ſubſtance; connected with which, is a ſtrip of tin foil, o, p. In the braſs ball, A, a hole ſhould be made, ſo that a plate or any other neceſſary appendage may be faſtened.

The excellence of this inſtrument conſiſts in the ready ſeparation of the gold leaf ſtrips, on the approach of any excited electric.

The inſtantaneous motion viſible in the ſtrips, on the contact of an evaporating fluid with the ball A, ſhews the vaſt ſuperiority of this to all other electroſcopes.

I ſhould have obſerved, that the dimenſions of parts in this inſtrument, are the following. ---- It is uſually about four inches in diameter, and five inches high. The diameter of the neck ſhould be regulated by the ſize of the braſs wire. The ſtrips are about two inches long, and one-fourth of an inch wide. Some ivory or wood ſhould be ſcrewed upon the extremity, B, or the ſtrips cannot be glued on. The tin foil is uſually fixed ſo high as to be on a level with the lower extremity of the ſtrip. However, I would prefer a veſſel of much larger dimenſions, ſo that wider and longer ſtrips might be uſed, and of courſe a greater ſurface expoſed to the electrified atmoſphere in the veſ-

ſel; and I would wholly exclude the tin foil and the braſs bottom, as having no other effect than that of diſcharging the atmoſphere before it can be examined.

III. The variety of ſtates in excited bodies, which I have juſt now deſcribed, and taught you to diſtinguiſh, is not confined to the ſurface of different bodies. It may be obſerved in the oppoſite ſurfaces of the ſame body; in different parts of the ſame fluid, and, in ſome caſes, of the ſame ſurface. The oppoſite ſides of excited glaſs are always *poſitive* and *negative*.--- At a diſtance from that portion of the atmoſphere, which gives poſitive ſigns, may be always found a portion which gives ſigns the

very reverſe: and it has been aſſerted that a glaſs ſtem, three feet long, when rubbed, will be found, on different parts of its ſurface, to ſeparate and cloſe the gold leaf ſtrips alternately.

IV. You will obſerve, that we ſcarcely know the time in which glaſs, wax, roſin, &c. loſe the powers they acquire by excitation. I have ſome reaſons for believing that a ſurface of this kind, if kept in air perfectly dry, may be kept, without any new friction, in a ſtate of excitation for years.

V. Bodies of any thickneſs may be excited. I have ſome glaſs cylinders in my poſſeſſion, of very great denſity, whoſe effects have

not proved ſenſibly leſs than others, which electricians, reaſoning a priori, would have preferred, as being much thicker. I have, likewiſe, excited glaſs *ſtems*, ſo as to ſhew equal power with *tubes* of the ſame diameter.

VI. The ſphere of an *excited electric*'s influence, or the diſtance to which it will extend its repellent or attractive effects, as ſhewn by the gold leaf ſtrips, we may ſafely ſay, will depend on the *dimenſions* and *goodneſs* of the excited electric.

The dimenſions, however, of this ſphere are very much diverſified by the different temperatures and humidity of the air. A few floating

particles of duſt will cauſe a variety of reſult; ſo will the opening of a door; an increaſe either of reſpiration or perſpiration in the operator; and, above all, the quantity of flying particles which are perpetually reſting themſelves on the ſurface of an excited electric.

Numerous efforts have been made to determine the law of electrical influence.---Lord Stanhope has proceeded mathematically, and diſcovered a moſt accurate agreement between the language of fact and the corrolaries, which he inferred from ſeveral abſtract propoſitions. Mr. Morgan, who is well known for his ſkill in calculation and finance, has furniſhed us with the

beſt method of determining this law experimentally.

FIG. III.

A is the convex extremity of an excited ſurface.

BC is a metallic rod, delicately ſuſpended on the point E.

CF is deſigned to contain any weight which may be applied to the extremity of the rod.

The apparatus ſhould be as light as poſſible, and is beſt made of reed and cork, covered with tin foil.

While the ſurface, A, is in an excited ſtate, B is brought within

a certain diſtance of it, and the weight, moved by its influence, is carefully obſerved. A ſimilar obſervation is then made at a ſecond, a third, and a fourth diſtance.

Varieties will be diſcovered in the reſult of theſe obſervations, proceeding from the impoſſibility of keeping the ſurface for any conſiderable time in the ſame ſtate of excitation. Theſe varieties, however, are trifling, and, in a vaſt number of experiments, the weights diminiſhed very nearly in the duplicate ratio of the increaſed diſtance.

HITHERTO I have directed your attention wholly to facts.--- We have, therefore, trod on firm ground. I ſhall now lead you ſome way into the region of probabilities, and endeavour, by combining the light of conjecture and experience, to give you a more general view of the circumſtances which I have repreſented as the mere effects of friction, or as having no other connexion with each other, than that of being the common attendants of one ſimple proceſs.

Why the friction of electrics is followed by the conſequences I

have juſt enumerated, is a queſtion immediately ſuggeſted by what you have ſeen and heard: I will now try to anſwer it.

All electrical appearances muſt proceed from *ſomething* whoſe nature is corporeal.

The truth of this propoſition is fairly inferred from the dilation of ſome, and the perforation of moſt bodies, by the paſſage of that which is hence called the electric fluid. Indeed, there are facts whoſe peculiarities at firſt ſight ſeem to contradict it. Amongſt others, is the impoſſibility of communicating motion to a rod, ſuſpended with the utmoſt de-

licacy, by conveying the largeſt attainable quantity of electricity through one of its extremities.--- If (it may be ſaid) a body ſtrikes in this caſe upon one end of the lever, be its quantity ever ſo ſmall, with a velocity that is abſolutely infinite, why does no degree of momentum take place? It may be anſwered briefly, that we can produce facts perfectly analogous to the preceding, whoſe circumſtances will not admit of the ſame doubt.

A cannon-ball, fired through the extremity of a wooden lever, very delicately balanced, will not move it; and this ſingularity might be adduced with as much juſtice to

prove that a cannon ball is nothing, as the preceding to prove that the cauſe of electrical appearances is not a *body*.

But if we admit the corporeal nature of that which is hence with accuracy called the electric fluid, let us attend to the neceſſary conſequences of what we admit:— 1ſt, That the electric fluid, like all other corporeal ſubſtances, is capable of *attracting* and of being *attracted*. 2dly, That in conſequence of this capacity, it enters into an union with other bodies, and that as the nature of the ſubſtances to which it is united may vary, ſo the degree of force by

which it is united may ſhew an equal variety. 3dly, That when the electric fluid is ſeparated from any body, this ſeparation muſt be the effect of leſſening the force by which it was united to that body, and thus giving the attractive force of another body the ſuperiority; or it muſt be the effect of very much increaſing the force of the third body, and thus deſtroying the equilibrium.

Suppoſe that any body, A, ſhould be capable of uniting to itſelf, or ſuppoſe the law of its conſtitution were ſuch as to admit of its attaching fifty particles of the electric fluid to itſelf, when near or in contact with another body, B, which likewiſe has an

attraction to thoſe particles; now in caſe any ſuch change ſhould take place as would add twenty particles to *B*, and leave thirty only in *A*, this change, it is evident, muſt proceed either from a diminution of *A*'s attracting force, or from an adequate increaſe of force in *B*.—Having deduced, from the corporeal nature of the electric fluid, ſuch conſequences as ſhew that when it is ſeparated from a body, it muſt proceed from a diminution of attractive force in the body that yields, or an increaſe of the ſame force in the body that takes; let us now examine how friction is likely to be the cauſe of ſuch changes.

By attending to the nature of friction, we ſhall find it to be nothing more than a ſucceſſion of preſſure or contacts of the different parts of different ſubſtances againſt each other: and the queſtion in the preſent caſe is this;---whether contact is neceſſarily attended with a change of attractive force in the different ſubſtances which are brought together? or whether the cloſe union of a particle of ſilk, hair, leather, &c. to a particle of glaſs, may be attended with a change of capacity in thoſe bodies to retain the electric fluid? ---If this queſtion be admitted, I think the particular mode in which friction operates, is eaſily diſcovered. I will explain myſelf by

a reference to what I regard as analogous facts.

Say, that the vitriolic, the nitrous, or marine acids, contain any particular quantity of heat; water likewiſe contains its due quantity; but when any two of theſe bodies are united, their capacity for retaining heat is diminiſhed, and conſequently, as ſoon as the mixture is made, a vaſt quantity of heat is diſcharged, and abſorbed by ſuch ſurrounding bodies as are ready to receive it.

Again, if ſalt and water be mixed, a combination is made, whoſe capacity for retaining heat is increaſed, and conſequently the mixture feels cold, or attracts heat

from any body which may come in contact with it. On thoſe who deny the corporeal nature of heat, the preceding inſtances will not (I am ſenſible) have any other effect than to ſerve as an elucidation. In my opinion, they are actual decompoſitions, ſimilar to what I am now explaining, in which one conſtituent body is let looſe, becauſe the force which attracted it, is diminiſhed by the union of two other bodies.

But if a particle of acid or water quits another ſubſtance, in conſequence of proximity or contact to a third ſubſtance, why, in like manner, may not a portion of the electric fluid be let looſe, owing to the greater or leſs capacity of

any two bodies when preſſed more cloſely together, than during their ſeparation.

The inſtances I have now produced, and indeed all other inſtances derived from a knowledge of chemiſtry, it may be ſaid, are applicable to fluid bodies only: whereas, when the electric fluid is let looſe, the effect proceeds, in moſt known caſes, from uniting the ſurfaces of two ſolid bodies.

A moment's conſideration muſt, I think, convince us, that the inſtances alluded to, differ in *degree* rather than in *nature*.

When fluids are united together, the contact is moſt complete:

for the particles of the body approach each other in a greater number of directions than when the ſurfaces of two ſolids are united. But there is the ſame contact in both caſes, with this difference only, that in ſolid bodies it takes place between two particles in one point. Briefly, then, my idea of the manner in which friction operates, is this;—when two electrics are preſſed cloſely together, while they *continue* together, they become capable of taking more or retaining leſs; and if this be allowed, I think the various appearances of bodies in a ſtate of excitation are eaſily accounted for.

However, it may be aſked, If the change produced in the ſur-

faces of two bodies be the effect merely of bringing the bodies nearer together, why does not contact alone produce the ſame effect? I muſt anſwer, that the ſeveral inſtances of ſpontaneous electricity enumerated by Wilcke, Epinus, and Others, appear to me to be ſo many evidences of the preceding theory. In thoſe inſtances we ſee the excitation of ſurfaces take place in ſuch circumſtances as will not rationally admit of any other cauſe than ſimple contact.

I. When ſulphur is melted into an earthen veſſel, if the veſſel be ſupported by a conducting ſubſtance, the ſulphur, when cold and ſeparated from the veſſel, is ſtrongly electrical.

II. If ſulphur be melted into glaſs veſſels, when cold, the glaſs, whether ſupported by electrics or not, will be poſitively electrical, and the ſulphur negative.

III. Melting ſealing-wax, when poured into glaſs cups, acquired a negative electricity; upon being ſeparated, the glaſs was poſitive.

IV. Melting ſealing-wax, when poured into ſulphur, became poſitive, and the ſulphur negative.

V. Sulphur was melted into metal cups: while they were together, no ſigns of electricity were diſcovered; but as ſoon as they were ſeparated, ſtrong ſigns of electricity were diſcovered: the

cup was negative, the ſulphur poſitive.

It is evident, I think, from the preceding facts, that contact alone is adequate to the production of electricity. I would add, that in the only caſe where contact may be applied moſt completely, electricity is produced in a moſt remarkable degree.----By Bennett's new electroſcope, we find that the ſlighteſt evaporation (which is certainly the union of watery with aerial particles) produces immediate ſigns of electricity. How rationally all the electrical appearances of our atmoſphere may be aſcribed to the ſame ſource, will be ſhewn more fully hereafter.

Before I quit this ſubject, I would explain to you the reaſons why, in many caſes, agreeably to the preceding hypotheſis, friction is neceſſarily much more powerful in its effects than preſſure.

Suppoſe A to be a particle of ſilk, brought into contact with a particle of glaſs, which I call B; by the increaſe of attraction conſequent upon the union, the combined bodies become capable of attracting a portion of the fluid, which, I ſay, is equal to five. Now A is no ſooner ſeparated from B, than another particle of ſilk comes in contact, and produces a ſimilar effect. The portion accumulated is now ten. A third comes into ſucceſſive contact with B, and adds

to the accumulation; and while the rubbing goes on, a ſeries of ſucceſſive effects is produced by a ſeries of ſucceſſive unions and ſeparations; for A is no ſooner ſeparated from B, than it is brought into that ſtate in which it was before the union, and conſequently diſpoſed to part with what it gained by the union. Now if you ſuppoſe A and B, inſtead of being ſingle particles, to be ſurfaces, all of whoſe parts operate at the ſame time, you may eaſily perceive how the effect would be increaſed.

In the preceding caſe I deſcribed the capacity of A and B to be enlarged by their union. If it had been leſſened, the ſubſequent effects would have been different;

for in ſuch a caſe, after the diſſolution of their contact, they would be diſpoſed to receive or re-take what they had loſt by their union. ---But I will ſpeculate no longer on the conſequences of friction, as elucidated from the ſuppoſed corporeal nature of the electric fluid, and from the changes ſuppoſed to take place on the attractive force of different bodies when brought into very cloſe contact with each other.---Let us now endeavour to account for the other appearances which we have deſcribed in this lecture.

I. The attraction of light bodies by excited ſurfaces is nothing more than the re-action of the fluid on thoſe ſubſtances which it

is leaving. If a magnet and a piece of iron be delicately ſuſpended at ſome diſtance from each other, both the attracting and the attracted body will be moved. In like manner, while the electric fluid is leaving the ſilken thread, Fig. I. it carries the thread, to which it is attached, towards the excited ſurface: but when the ſilken thread receives the fluid, it is apparently *repelled* by the excited ſurface; for the courſe of the fluid is then into the ſurrounding air, and conſequently its direction becomes the direction of the thread.

II. The reaſon why moiſture diminiſhes the power of excitation will be explained hereafter: but

the increaſe of excitation by the moderate uſe of oil, &c. (if the principles I have already laid down be admitted) may in my opinion be aſcribed, with ſome probability, to the more perfect contact which is thus produced, and perhaps to the greater change which is produced by the contact of ſome than of other bodies.

III. It is obvious, if we have rightly accounted for the effects of friction, that the thickneſs of a glaſs cannot materially affect its power of excitation; for the particles at the ſurface only operate, and the diminution or increaſe of their capacity cannot much depend on the quantity of the ſame matter which is internally annexed to them.

IV. If a ſurface have loſt or gained any quantity of electric fluid, it is evident that the ſigns of excitation will remain till another body is brought near enough either to ſupply the want, or take away the ſuperabundance. Air is not capable of producing ſuch effects, and conſequently, while air alone ſurrounds an excited body, we cannot well expect that the duration of years would produce any change, either in its poſitive or negative ſtate.

We have hitherto confined ourſelves to the moſt obvious effects of excitation, or to the changes attendant upon friction in or near

the ſurfaces of the bodies, which, from the capacity of being excited, are called ELECTRICS. As we advance, the machinery we employ, to produce the appearances of electricity, become gradually more complicate. Thus far we have made uſe only of a dry piece of glaſs, roſin, amber, &c. and a piece of ſilk, ſkin, hair, or leather, as a rubber. For convenience ſake, in applying the power of friction, the ſurface moſt generally employed by modern electricians, is that of a cylinder; againſt one part of which, a cuſhion filled with hair, and covered with leather, is kept with a light preſſure, ſo as to operate ſucceſſively on a conſiderable portion of the cylindrical ſurface, as it moves round.

The contact of the two electrics is generally increaſed by a piece of ſilk, which is as wide as the cuſhion, and, extending from its upper extremity, covers near one-half of the excited ſurface.---I ſhall hereafter give the rationale, and a minute deſcription of this and every other part of an electrical apparatus.

You have ſeen, in the laſt lecture, that a body of the fluid was collected on that part of the glaſs which had juſt undergone the friction. It is this collected body of the fluid that will cauſe the appearances obſervable when the following addition is made to our apparatus.

FIG. IV.

On a piece of glaſs, AB, (the longer and firmer it is, the better, provided you do not make it either clumſy or inconvenient) fix a metallic tube, DC, in length about two feet, and in diameter four inches nearly. Let this tube be carefully freed from all edges, points, and other prominences: to the ſide of this tube, which is beſt known by the name of CONDUCTOR, let a row of points be faſtened, ſuch as gh; and while the glaſs is excited, let theſe points be placed oppoſite that part of the glaſs which has juſt been rubbed, or which is juſt quitting the ſilk. In a few moments you may ob-

ſerve a brilliant ſpark paſſing from the points to the cuſhion. If you bring your nuckle or wriſt near the conductor, the ſpark will ſtrike into it. An acute noiſe may be perceived at the ſame inſtant, together with a diſagreeable ſenſation in the ſtricken part; and, in caſe the metallic tube and cylinder be large, a violent ſhaking will be felt in the joints and elbows.--- The leading circumſtances which demand our attention in the preceding operation, are, the ſound of the ſpark,---the varieties dependent upon the various forms of the conductor,---the figure of the ſpark ---its length,---the violence or force of the ſpark,---and, finally, the brilliancy of the ſpark.

I. THE SOUND.

WHEN the termination of the conductor is ſharpened, by annexing to it a ſmall ball, not exceeding an inch in diameter, the ſpark is lengthened, and the noiſe is very much diminiſhed. The noiſe is loudeſt when the ſpark is made to ſtrike from one flat ſurface to another; for in this caſe its courſe is ſtraight, and of courſe that percuſſion of the different particles againſt each other, which cauſes ſound, is moſt violent. The deflections or zigzag of a ſpark is a proof that the fluid, in its paſſage, finds ſome difficulty (if I may be allowed the expreſſion) in con-

quering the obſtructions it meets: therefore, as this zigzag increaſes, you may always obſerve that the ſound deadens, or becomes leſs acute. When the ſpark is made to paſs thro' a tube of glaſs ſtopped at both ends, the noiſe is entirely huſhed. In making this experiment, the glaſs tube muſt be very dry, otherwiſe it will be impoſſible to prevent that whole quantity of fluid, which is accumulated near the conductor, from eſcaping along the ſides of the glaſs.

In a very early period of this ſcience, an electrician obſerved ſome analogy between the ſnapping of a ſmall ſpark and the exploſion of a thunder-cloud. I have often been puzzled, while attempting to

fix upon that circumſtance of ſimilarity which ſtruck Mr. Grey's imagination; but I always concluded that he owed more in this inſtance to his good fortune, and his boldneſs as a theoriſt, than to his penetration as a philoſopher. You will ſee, however, in a ſubſequent part of theſe Lectures, that the acute, cracking, undivided noiſe of a ſpark, and the deep, reverberating roar of the lightning, are identical effects of the ſame cauſe, differing in degree only, and not in nature.

II. THE VARIETIES DEPENDENT UPON THE FORM AND DIMENSIONS OF THE CONDUCTOR.

Numerous are the differences which reſult from varying this part of the apparatus. The whole of its

action ſeems to conſiſt in ſpreading that fluid which is accumulated on the cylinder to a body of air, which the fluid would not otherwiſe reach, and in promoting the inſtantaneous diſcharge of the loaded air, when circumſtances are ſo managed as to admit of a diſcharge. If, after the air is loaded, the conductor were annihilated, no change would take place in the accumulation of the fluid; for the whole of the charge would ſtill remain in the ſurrounding air. On the other hand, the air would never be diſcharged inſtantaneouſly or all at once, unleſs the conductor be reſtored to its former ſituation.

The whole of what I have now ſaid, is proved by experiment.---

When a thick chain, or a great number of balls, connected with each other, forms a conductor; when, moreover, your contrivances are ſo managed, that the chain or balls, as ſoon as the air is charged, ſhall drop into an inſulated cup,--- on removing the cup, you will find that the conductor has ſcarcely any ſigns of electricity: whereas the ſtate of the air, in which the chain was ſuſpended, is ſcarcely altered; for, upon raiſing the chain again into the ſame portion of air, a ſpark will ſtrike from it, on the application of the hand, or of a metallic ſubſtance. What I have juſt now ſaid, will be ſufficient to convince you that, provided your conductor be ever ſo large, none of the fluid, which paſſes from it,

is collected in itself: the atmosphere alone is loaded, and to *this only* you must confine your ideas of the *loss or superabundance which takes place.* I call your particular attention to these circumstances, as I have seen the most extravagant errors committed, in the fabrication of some modern theories, owing either to an ignorance or a misconception of them.

The metallic nature of the conductor is the next particular which commands our observation.

If it be made of wood, when applied to an excited surface, a certain portion of the surrounding air will be charged as in the preceding case, but the air will receive the

fluid very ſlowly: beſides, whatever charge is conveyed to the atmoſphere by wood, cannot be diſcharged inſtantaneouſly, as in the inſtance of metallic conductors; but on the application or approach of a metallic ball, the fluid paſſes to it in a continued, ſilent ſtream, or in the form of a ſpark attended with little or no ſound. In other words, ſome time is required to unload the charged atmoſphere of the fluid which it contained.

If, inſtead of wood, a piece of glaſs, of ſealing-wax, or any other body which is capable of excitation, be placed in the circumſtances of the metallic conductor, no change whatever will take place. I mean to ſay, that ſo much air

only will be charged, as we find loaded or charged when no conductor is brought near the excited cylinder.

From this peculiar property electrics have received the name of NON-CONDUCTORS;---and in the ſame property we find the reaſon why metallic conductors, before they can be charged, are placed upon them; for having no power to convey the fluid from one part of the atmoſphere to another, they afford no vent or paſſage for eſcape to that portion of the fluid which is accumulated around or near the metallic conductor.---- When any electric is employed to ſupport the metallic conductor, it is then called an INSULATOR, as

it is in many other caſes where it is uſed for ſimilar purpoſes.

III. THE FIGURE OF THE SPARK.

This depends entirely on the ſuperficial dimenſions of that part from which it proceeds, and of that body which receives it.

If the ſpark be taken from a ball, two or three inches in diameter, its paſſage will be perfectly ſtraight.

If it be taken from a little ball, half an inch in diameter, the form of the ſpark will be a zigzag.

But if the conductor ſhould terminate in a point, or in an edge, or

any acute protuberance, the fluid paſſes to ſuch conducting bodies as are brought near it, in a diverging, uninterrupted ſtream, or, in caſe no ſuch bodies are near it, into the air itſelf; ſo that, unleſs the machine be very large indeed, it is impoſſible to procure any thing like a ſpark at the diſtance of more than half an inch from the point. If, however, the point or edge, inſtead of protruding, be forced back, ſo as to be on a level with the ſurface of the conductor, the ſpark may be formed as completely as if the part from which it ſtruck were perfectly ſpherical.

Hitherto I have merely ſhewn you how far the formation of the ſpark depends on the figure of the part

from which it *ſtrikes*: the ſame effect, it is to be obſerved, depends at the ſame time very much on the figure of the part which *receives* it. No ſpark is formed when a point is brought near the conductor, or when the body which receives the fluid is made acute: but if the point be buried in a ball, ſo as not to protrude beyond its ſurface, the ſpark is perfectly formed; nay, a metallic point may be circumſtanced ſo as to receive a ſpark, in caſe that point be faſtened to a metallic ſubſtance which is ſeparated from the hand, or any other conducting body connected with the ground by a piece of dry glaſs, whoſe length, together with that of the point's ſeparation from the conductor, muſt not be greater

than the common ſtriking diſtance of the ſpark in air.

IV. THE LENGTH OF THE SPARK, OR THE VARIETY OF DISTANCE THROUGH WHICH THE SPARK STRIKES FROM THE CONDUCTOR.

This depends upon ſeveral diſtinct circumſtances, viz. The length and diameter of the conductor; the termination from which the ſpark ſtrikes; the dimenſions of the cylinder, or the diſtance of the cuſhion from the point which receives the collected fluid; and, finally, the poſition of the conductor.

1. If the length alone of the conductor be increaſed, the ſpark

is rather ſhortened than prolonged by the change. This effect was obſerved by Dr. Prieſtley, in a very early period of his electrical purſuits. If I remember rightly, His experiment was made with many yards length of wire, whoſe diameter did not exceed one-fourth of an inch. The extremity of this wire, when charged as high as poſſible, would not yield a longer ſpark than a conductor of two feet in length, and two inches in diameter. In the "Scelte D'Opuſcule," may be ſeen a diſſertation of Signior Volta's on the ſame ſubject; from which it evidently appears, that ſeveral rods eight feet in length, and half an inch in diameter, ſuſpended at the diſtance of twelve inches from each other,

would not afford that length of ſpark which he got from a conductor of the ſame length, and about twelve inches in diameter. Mr. Brook of Norwich has, with great induſtry, purſued this ſubject. I have ſeen him connect near twenty rods (covered with tin foil) about ſix and a half feet in length, and three-fourths of an inch in diameter, at the diſtance of near a foot from each other. The whole apparatus, when complete, reſembled a large gridiron, ſuſpended by glaſs rods from his cieling.--- From ſo large an extent of conductor, I do not remember ever to have ſeen a ſpark ſtrike, exceeding ſix inches in length:--- whereas, from a conductor eight feet in length, and five inches in

diameter, I have often ſeen ſparks ſtrike, nine inches one-fourth long, though the ſame cylinder was excited in both caſes.

From the preceding facts, it is ſufficiently clear, that increaſe of length in a conductor does not contribute to the length of the ſparks you produce. The queſtion which occurs from this concluſion is very obvious.

2. Suppoſe we increaſe length and diameter at the ſame time, will the effect be different? I can, from my own experience, anſwer in the negative. By the moſt powerful excitation of a cylinder fourteen inches in diameter, the ſpark afforded by a conductor eight

inches in diameter, and twelve feet long, did not equal half the length of that which I procured from the ſame cylinder with a conductor equally thick, but ſhortened to ſix feet. I have many reaſons for believing that a conductor of three feet in length, and ſixteen inches in diameter, would have yielded a longer ſpark than either of the preceding.

Let us, however, proceed to another circumſtance, on which the length of the ſpark very much depends.

3. I mean the proportion of your cylinder's dimenſions to thoſe of your conductor. If the diameter of this part of your ma-

chinery be ſmall, the conductor, long before it is *fully* charged, will diſcharge itſelf over the ſurface of the cylinder into the rubber.--- When the conductor is very long, it is a ſmall cylinder indeed that will charge it to a very conſiderable height. ---- I have ſeen Mr. Brook apply a cylinder, four inches only in diameter, to the gridiron conductor which I have already deſcribed, and the ſpark afforded was ſo violent, that I could hardly endure it: whereas the ſpark from a conductor of ſix inches diameter, and about five feet in length, was ſo ſoon charged with power enough to ſtrike acroſs the cylinder, as to yield a very trifling ſpark. The infantine ſtate of this ſcience will not allow us to point

out, with any preciſion, the ſpace through which the charge of a particular conductor will ſtrike. —— Twenty-three inches, I think, has been the greateſt length of a ſpark afforded by a conductor ſix feet long, and twelve inches in diameter. I obſerved, during the operation of this machine, that a longer ſpark could not be obtained, becauſe the charge paſſed over the cylinder, which was 18 inches in diameter, to the cuſhion.

There is a limit in theſe caſes which our experience has not yet determined; but I would call your attention to a fourth circumſtance on which the length of the electric ſpark very much depends.

4. The poſition of the conductor. ---It was formerly, nay, very lately, the cuſtom to place the conductor ſo as to form right angles with the ſide of the cylinder;---one diſadvantageous conſequence of this method was, the abſolute neceſſity of uſing no more than three or four points at the diſtance of three-fourths of an inch from each other for the collection of the fluid. A great quantity of it, therefore, was allowed to eſcape to the wooden caps and the cuſhion.---Beſides, this poſition removed the conductor entirely out of the atmoſphere of the cylinder. The effect of this, and of the other diſadvantages which I have mentioned, may be immediately perceived by com-

paring thoſe machines in which the rectangular poſition is retained, to ſuch as adopt the alteration firſt obſerved in Mr. Nairne's patent machine.

5. But the ſize of the ball, *from* which the fluid is received, is another circumſtance connected with the length of the electric ſpark.

When I have experienced an impoſſibility of making the fluid ſtrike over more than four inches from the ſides of a conductor, I have been generally able to get a ſpark ten inches long, from an inch and quarter ball, placed at the extremity of the ſame conductor.--- If the ball be reduced to three-fourths of an inch, the fluid will

ſtrike in ſucceſſive flaſhes, and will not paſs in a collected body, till the diſtance between the ſtriking and the receiving body be very much diminiſhed.

Having fully conſidered the ſound, the form, and the length of the ſpark, we ſhall now proceed,

V. TO ITS VIOLENCE OR FORCE.

This does not increaſe with its length: on the contrary, it is evident, from our feelings, as well as from ſome other teſts, that if the ſpark be received from the body of the conductor, and not from a protruding ball annexed either

to its ſide or its extremity; that in the former caſe it is much more painful than the latter.

Beſides, a very large conductor affords but a very ſhort ſpark, which, compared with others which ſtrike through a body of air ſeven times longer than that of its own paſſage, ſhews a manifeſt ſuperiority of force. Signior Volta has given particular attention to this ſubject: he eſtabliſhes the fact; but we are far, ſtill very far, in this, as in many other caſes, from an approach to any determined law.

Dr. Prieſtley, judging by the teſt of his feelings only, has obſerved, that if a metallic ball be

placed between the conductor and the ball which receives its contents, the force of the ſpark is much increaſed. I have often attended to this circumſtance, and I have always experienced feelings ſimilar to thoſe deſcribed by Dr. Prieſtley.

In the "Scelte D'Opuſcule," may be ſeen a moſt prolix and parading deſcription of a method to increaſe the ſtrength of the ſpark, by a Signior Litta, whoſe ſingular garrulity is not leſs remarkable than the error which he commits; for, after awakening the curioſity by ſeveral quarto pages in praiſe of his own diſcovery, the whole terminates with an obſcure account of his applying a Leyden phial, inſtead of a conductor, to the excited cy-

linder, and, conſequently, of his miſtaking the *violence* of a *ſhock* for the *force* of a *ſpark*. But,

6. The moſt ſingular circumſtance of the electric fluid, in its paſſage through the air, is the light.---Provided the receiving and the diſcharging balls be not diſtant from each other above half an inch, a continued ſtream of the moſt brilliant light will appear during the excitation. When the diſtance of the balls is increaſed, ſparks, equally brilliant, will follow each other in a moſt rapid ſucceſſion. When, however, the diſtance equals four inches, unleſs your machine be a very large one, the appearance of the ſpark will begin to vary, as you vary the

form of what terminates your conductor; for a ball, an inch in diameter, will afford a ſpark, whoſe edges will be purpliſh, and from which ſeveral ramifications will diverge, whoſe colour will be altogether purple or indigo.---The brilliancy of the ſpark is greateſt when it paſſes through a tube, and its colours are weakeſt when it is moſt divided. In caſe the termination of your conductor be a point, then the bruſh which paſſes into the air is of a bluiſh colour. As we proceed with this ſcience, the ſingularities of the electric light will be frequently demanding our attention.

I will now remind you, that the detail of circumſtances, which I

have juſt laid before you were the conſequences of a very ſimple addition to our apparatus, or of placing a metallic tube of certain dimenſions, parallel or perpendicular, to the excited cylinder. We ſhall now proceed to make another addition to our apparatus, whoſe effects, when compared with thoſe we have juſt enumerated, will be found to differ in degree only, or to flow from the immediate operation of the ſame cauſes. As, therefore, what will be ſaid to explain the preceding may be applied with eaſe to the explanation of many other appearances, I ſhall go on with a ſimple account of facts, nor ſhall I ſtop in this progreſs, till you are ſo well furniſhed

with experience as to be qualified for taking a more general view of the ſcience.

INSTEAD of the conductor or inſulated metallic tube, whoſe effects, when applied to an excited ſurface, appeared from the circumſtances and facts enumerated in my laſt Lecture, I ſhall now ſubſtitute a cylindrical glaſs veſſel covered with tin foil on the inſide and the outſide, having a ſmall part only of its ſurface uncoated. This part extends from the edge of the glaſs on both ſides to the diſtance of two or three inches. Connected with the tin foil on the inſide of the veſſel is a wire, whoſe upper extremity is in contact with the excited electric. Fig. V. explains the apparatus. During the excitation

of the glaſs, when thus circumſtanced, the following appearances take place. The influx of a torrent of the electric fluid into the inſide of the glaſs veſſel; a luminous ſtar at each receiving point of the conductor, which, after the excitation of ſome ſeconds, is attended by the appearance of ſeveral little ſtreams of the fluid paſſing from the points to the cuſhion.

A ſudden exploſion very ſoon ſucceeds, together with a moſt brilliant diſplay of the fluid in its paſſage from the inner to the outſide coating.

This effect is called the *ſpontaneous diſcharge* of the glaſs veſſel, which is known amongſt elec-

tricians by the name of the *Leyden phial.*

If, however, at any period of the operation, previous to the ſudden exploſion or ſpontaneous diſcharge, you connect the wire and the outſide coating by a metallic rod, with metallic balls at its extremities (ſee Fig. VI.) the ſame exploſion, in a leſſer degree, will take place, and the ſame brilliancy of light will appear.

But in both caſes, if you examine the glaſs veſſel after the diſcharge, you will find that a ſmall portion of the electric fluid ſtill remains, and is capable of being removed by forming a ſecond metallic communication between the

inſide and the outſide coating. If, previouſly to the diſcharge of the jar, you place one hand on the outſide, and then touch the wire with the other hand, the fluid then paſſes through your arms and body, in which is experienced at the inſtant a moſt violent and painful concuſſion.

A great number of diverſities may be obſerved in the effects I have now briefly enumerated, by the ſeveral poſſible variations which may take place in the following parts of the apparatus.---1ſt, The glaſs veſſel. 2d, The coating. 3d, The interval of uncoated glaſs. 4th, The interval of air between the wire and the glaſs. 5th, The metallic or other ſubſtances which

are employed to make the diſcharge.

I. THE GLASS VESSEL.

If this be very thin, and the uncoated interval not leſs than an inch on each ſide of the veſſel, the proceſs of charging will be ſoon followed by a harſh, craſhing noiſe, and in ſome part of the glaſs, upon examination, will be found a ſmall hole, from which a multitude of cracks will diverge, ſo as to give it the appearance of a ſtar. If the glaſs be very thick, I mean about one-fourth of an inch thick, the ſpontaneous diſcharge will happen ſooner; but the violence and quantity of the fluid which is now diſcharged will be

much inferior to what paſſes from one ſide to the other when the glaſs is thinner.

The diverſities which proceed from varying the form of the glaſs veſſel are not very numerous or important. When the dimenſions of the neck are very ſmall, the wire is ſo near the uncoated part of the glaſs, as conſiderably to haſten the ſpontaneous diſcharge.

No change of reſult takes place if the coated glaſs, inſtead of being cylindrical, be either cubical, hexagonal, or of any other figure.

I ſhould add, that all electrics, when ſimilarly treated, diſplay ſimilar phœnomena. In common

uſe, however, glaſs is generally preferred, becauſe it is moſt eaſily moulded into a proper form and thickneſs. It has, notwithſtanding, one quality in which it is inferior to every other electric. Its power of attracting moiſture, which, when collected from the ſurrounding atmoſphere on the uncoated interval of the veſſel, renders it incapable of being charged without freſh wiping and drying. This inconvenience, when a great number of phials is uſed, is attended with great trouble. Of all ſubſtances which experience has brought to my acquaintance, talc is the moſt free from diſadvantages of this kind. I have charged a lamen of it, and after the expoſure of ſome hours to the air, without any particular

attention to its inſulation, I have found its charge ſcarcely diminiſhed.

II. THE COATING.

The neceſſity of a metallic coating, for the production of the effects already deſcribed, requires your attention. Without this coating, the phial, if clean and dry, will take but a very trifling charge, and even the trifling quantity of fluid, which is thus collected, cannot be diſcharged all at once. By forming a metallic connexion between the outſide and the inſide, ſcarcely any reſemblance to an exploſion is produced. Inſtead of a ſnap, you hear a whizzing noiſe only; and inſtead of a ſpark, a

ſmall ſtream appears in its paſſage from the wire which touches the *inſide*, to the ball which is connected with the outſide. The earlieſt appearances of the Leyden phial were diſcovered by putting water into it; but experiments prove that water (even when the veſſel is filled with it to a proper height, and when it is covered on the outſide to the ſame height) will not admit of a perfect diſcharge, as may be eaſily perceived by the ſound of the exploſion, and the faint colour of the ſpark.

Muſchenbrook, and ſome other electricians, who were amongſt the firſt that experienced the electric ſtroke, muſt have allowed fear very much to have inflamed their

imaginations, when they gave that account of it, in which the loſs of kingdoms is repreſented as trifling, compared to the dangers of bearing a ſecond blow: for the ſize of their phial, the circumſtance of its being filled with water; the probability that the outſide was not covered with moiſture or any other conducting ſubſtance, ſo as to ananſwer the coating on the inſide; theſe, together with many other particulars whoſe effects tended to leſſen the charge, muſt have rendered the ſtroke they felt very inconſiderable indeed.

I know of nothing beſides the acids which can act as a coating with any degree of perfection approaching to that of the metals.

The acids, however, cannot be laid on with any convenience or permanence, or with any protection againſt the dangers which are well known to ſuch as are acquainted with their corroſive qualities. I have as yet found no difference between the different metals, in their goodneſs, as coatings. I have tried braſs filings, mercury, lead, tin foil, &c. and they are all equally powerful in their effects.

III. THE UNCOATED PART OF THE GLASS.

If any duſt, moiſture, or dirt, be ſpread over this portion of the glaſs, (agreeably to what I have already obſerved) all attempts to charge the phial will be ineffectual.

If a ſmall protruſion of the metallic coating extends to the diſtance of one-third or half an inch on the uncoated glaſs, the ſame inconvenience will be experienced in ſome degree, and this circumſtance urges the neceſſity of having the edge of the coating cut as evenly as poſſible.

The proper dimenſions of the uncoated part, it is my intention to determine (if I can) by ſome future experiments. I would, however, obſerve that theſe dimenſions are by no means proportional to the magnitude of the ſurface, but to the height of charge which the veſſel is capable of taking. If the glaſs be very thin, and the coatings be diſtant from each other

ſix inches, the glaſs always breaks when the charge is carried to any great height. If the glaſs be thick, the diſtance of the coatings may be ten or twelve inches, and no fracture take place. I have ſtripped the coating off the outſide of a pint phial, nine inches high, and two inches in diameter, till it was all uncovered, excepting one inch of the ſurface, meaſuring from the bottom. In this caſe the phial, unbroken, would diſcharge itſelf from the wire connected with the inſide, over the diſtance of nine inches on the outſide.

When the uncoated interval of the glaſs is made very hot, the ſpontaneous diſcharge is very much haſtened: but if the uncoated in-

terval be dirtied to a certain degree, the ſpontaneous diſcharge is much retarded, and the phial enabled to take a much higher charge than it would otherwiſe admit of. I cannot ſpeak the language of Experience with regard to the efficacy of covering the uncoated part of the phial with a good varniſh. When experiments are made in a humid atmoſphere, I ſhould expect that a great deal of toil might be ſaved by ſuch an attempt to keep off the moiſture.---If the varniſh be in the leaſt glutinous, the little particles of duſt, which float in the air of the room, will ſtick, and carry off a vaſt quantity of the fluid,---eſpecially when the charge gets to be very high.

When the phial is diſcharged in the dark, the appearance of the uncoated part of the glaſs is very curious. From all parts of it a croud of luminous ſtreams may be ſeen pouring, as it were, from the edge of the glaſs towards the metallic coating. This appearance proceeds from the partial charge which the uncoated glaſs has received, and which, when the diſcharge is made, becomes luminous in the ſeveral tracts which it follows. I would likewiſe obſerve that the cauſe which operates in this inſtance, is likewiſe the cauſe of that ſecond charge which every bottle is found to have after the firſt diſcharge is made; for the uncoated part is but partially diſcharged, owing to the want of a

good metallic connexion between the ſeveral parts of the glaſs; but the reſidue, which is thus left, is ſoon conveyed over the whole internal ſurface of the phial, and thus communicates to it a ſmall ſecond charge.

IV. THE DISCHARGING ROD.

When this is made of an uninterrupted piece of metal, the electric fluid paſſes through it without affecting the hand which holds it.

But if the rod conſiſts of two metallic pieces tied together ever ſo cloſely, and if you hold it above the juncture during the diſcharge, you will feel a ſhock in a ſmall degree. This is owing to the imperfection of the contact which is

formed between the two pieces, and to the ſmall reſiſtance made by the interval of air exiſting between them.

When the termination of the rod (I mean that which is applied to the wire) is not more than half an inch in diameter, a hiſſing noiſe will be heard previous to the diſcharge, and the exploſion will be much inferior to what takes place when a larger ball is uſed.

If the termination be a point, it will be impoſſible to procure a diſcharge with it, unleſs you bring the point very rapidly indeed towards the jar, or unleſs the other extremity be ſeparated from the coating by a ſmall interval of air.

To procure a perfectly inſtantaneous diſcharge, the rod muſt be made of metal · all other bodies will either diſch: ge the phial partially, or not at all.

In a ſubſequent part of theſe Lectures I ſhall call your moſt patient attention to this difference in the conducting powers of bodies. It is time, however, that I ſhould amuſe you by breaking, for a while, the plain ſeries of facts which we have, without interruption, extended thus far. Let us now attempt, by the aid of well-founded principles and fair deduction, to obtain a more general view of the ſcience, and penetrate, if poſſible, into the cauſe of many, amongſt the numerous, effects which we have deſcribed.

THE leading principles of our theoretical knowledge in the ſcience of electricity, are the following.

1ſt, The corporeal nature of that ſomething on whoſe operations electrical phœnomena depend.

2d, That the union of this with other bodies depends on an attractive force, or on the mutual attraction ſubſiſting between that corporeal ſomething, which is called the electric fluid, and the body to which it is united.

3d, That of the electric fluid there is a *certain quantity* only re-

tained by different ſubſtances; and moreover, that without ſome alteration in their conſtituent parts, it is impoſſible they ſhould retain more than that certain quantity, or loſe any portion of it. Several corrolaries, which flow from the eſtabliſhment of theſe leading principles, will, in conjunction with the application of the principles themſelves, enable us to explain ſeveral electrical appearances.

1ſt, For the corporeal nature of that ſomething, on which electrical appearances depend, I have already given you my reaſons.

2d, To prove the mutual attraction ſubſiſting between the electric fluid and other bodies, nothing is

neceſſary but the eſtabliſhment of its corporeal nature; for without the capacity of attracting and of being attracted, it would want one of the eſſential properties of matter. However, if you have recourſe to your own memories, you muſt recollect facts which eſtabliſh this principle on the baſis of experience. The ſeparation of the pith balls and other light ſubſtances, when charged with the fluid, together with the invariable motion of feathers, particles of duſt, &c. in the direction of the fluid, ſhew that the two ſubſtances move together, becauſe they adhere or are united to each other by an attractive force.

I would add, that when the elec-

tric fluid eſcapes from a quantity of water into the ſurrounding air, it always carries with it a portion of watery particles into the ſurrounding atmoſphere, and thus produces a very conſiderable evaporation.

The cool current of air, which may be felt when the fluid is paſſing from a metallic point, ſpeaks a ſimilar language.

But your eyes may bear teſtimony to the effect of the ſame mutual attraction in the following experiment. Let the charging wire of a Leyden phial, I mean that which connects the conductor and the inſide ſurface of the glaſs, be covered with linſeed oil: when

the phial is charged highly, the fluid will begin to ſpit from the wire, and the oil will fly off in the ſame direction with it, forming, in its various paſſages, ſeveral little beautiful ſtreams. An experiment frequently made by itinerant lecturers, to amuſe their ſpectators, is of the ſame kind. Let a piece of ſealing-wax, in a melting or ſoftened ſtate, be annexed to a conductor: if the conductor be charged, and a metallic ball brought near the wax, the electric fluid, in paſſing to the ball, will carry with it a continued ſtring of the fuſed wax.

3d, There is a certain quantity of the electric fluid in all ſubſtances, the increaſe or diminution

of which is altogether impoſſible, without ſome previous alteration in the conſtituent parts of thoſe ſubſtances. Numerous are the moſt deciſive experiments which ſupport this propoſition. I will preſent you with a few of the principal.

1. Let a Leyden phial, of any magnitude, be ſuſpended from your conductor, in ſuch a manner as to have no contact with any thing but the wire which faſtens it to the conductor: in other words, let it be inſulated by a body of air, ſo as to be eight or ten inches diſtant from the table the machine reſts upon, or any thing elſe of a conducting nature that is connected with the ground. In theſe circumſtances, the excitation of the

largeſt cylinder will not communicate the leaſt charge to the phial, as you may be convinced by the application of a diſcharging rod, or by any one of thoſe numerous particulars which we have deſcribed as the invariable attendants of a diſcharged phial.

2. Let a glaſs, of the form repreſented in Fig. VII. be uſed as a Leyden phial; let the knob A be faſtened to a braſs wire, which, during the expoſure of it to a charged conductor, touches the bottom of the glaſs AB; let the metallic coating on the outſide not riſe above one-third the height of the glaſs; fill the inſide to the very neck with any body, either fluid or ſolid.--- Now in caſe the veſſel, when applied to the charged conductor,

be inſulated as in the laſt experiment, we ſhall find it incapable of receiving a ſingle atom of the fluid, whatever be *the bulk or magnitude of the body* contained in the glaſs. I would obſerve, that the leaſt protuberance on the outſide coating, or the incautious approach of a conducting point connected with the ground, or one out of a variety of other minute circumſtances, when diſregarded, will cauſe a moſt important diverſity in the preceding experiment. Hence it is, that ſome perſons have been led, by their own ſlovenly inaccuracy, to reject the only rational theory of the Leyden phial. I would further obſerve, that the preceding experiments ſhew only that no addition of the

electric fluid can be made to any ſubſtance whatever. I will now proceed to give you experiments with an intention to prove that when an addition is made to one ſurface of a body, a quantity, equal to what is added, is immediately loſt from the oppoſite ſurface.

3. Fig. VIII When the phial is inſulated, let the metallic ball A, annexed to its charging wire, be brought within a certain diſtance of the ball B, which protrudes by a metallic connexion from the conductor. Let C, connected by a wire with the ground, be as far from the outſide of the coating as A is from the ball B. When the cylinder is excited (or, to uſe the language of electricians, is made

to work) you may perceive a number of ſparks ſtrike from the outſide to C, equal to thoſe which contemporaneouſly paſs from B to A. However, this experiment is not the only proof of the propoſition in queſtion. If C be connected with the inſide of another phial, which is not inſulated, you will find that the quantity which has paſſed from the outſide of the upper phial, to the inſide of the lower, is exactly equal to that which is accumulated on the inſide of the upper phial.

4. You will ſee hereafter, that water, ſpirits of wine, and ſome other liquids, will not allow more than a certain quantity of the electric fluid to paſs through them.---

On this principle is founded the following experiment, which I deſign ſhould be acknowledged as a further proof of the propoſition in queſtion.

Fig. A F is an inſulated phial; B D an inſulated tube filled with water; E the prime conductor; C, as in the preceding experiment, a metallic ball, connected with the ground: when the conductor is charged properly, a very faint ſpark will paſs from E to D contemporaneouſly with another from B to A, and a third from F to C: theſe ſparks will all reſemble each other in ſound, ſize and colour. If the tube B D, filled with water, be removed from between A and F, and placed between F and C, the ſame appearances will take place; for the

water will allow ſo much of the fluid only to paſs from the outſide, in this inſtance, as is conveyed upon the inſide in the preceding, and the ſpark from A to E will now be no greater than it was when BD was ſituated between thoſe points. A great number of experiments might be eaſily ſhewn on the preſent occaſion, which vary a little in their circumſtances; but all of them would ſpeak the ſame language with the preceding, and, in my opinion, remove all doubts with regard to the truth of our propoſition, viz. that bodies can receive no addition to their natural ſhare of the fluid, and that ſuch bodies as are capable of being charged, loſe from one ſurface as much as can be accumulated on the oppoſite ſurface.

The latter part of the propoſition is confined to electrics or bodies capable of being excited.--- Of non-electrics, or ſuch bodies as metals, &c. it is here to be obſerved, that it is not only impoſſible to add to their natural ſhare of electricity, but that they are likewiſe incapable of having their oppoſite ſurfaces affected ſimilarly to thoſe of glaſs, &c. On the contrary, the inſtantaneous diffuſion of the fluid through their whole maſs, be it ever ſo large, and be the quantity of the fluid ever ſo ſmall, is that peculiarity from which they derive the name of conductors, and which, in a moſt remarkable manner, diſtinguiſhes them from electrics.

THE mode in which the force of attraction operates, when electrics are charged, is capable, I think, of eaſy explanation.

Let us ſuppoſe ABCD, Fig. X. to repreſent a certain thickneſs of any electric, at whoſe ſurface, and in whoſe ſubſtance, the electric fluid exiſts as a component part.

In caſe the particles at one ſurface AC, be taken away, it is clear that the force which attracted them is diſengaged for attracting any uncombined particles which come within the ſphere of its activity.

If the force which unites the electric particles within the body, to the ſubſtance of that body, be leſs than that which is active at the ſurface, then it is clear that the deficiency will be ſupplied ab intra, or from the ſubſtance of the body, and that the deficiency, thus cauſed, will be again ſupplied by any ſimilar ſubſtance that comes in contact with it; ſo that the fluid will appear to paſs through the body, with an eaſe proportionable to the ſmallneſs of that force within the body which obſtructs the removal of its inherent particles.

If the force which unites the electric fluid to the internal parts of the body, be greater than that which is active ab extra, the defi-

ciency then will not be ſupplied from the body itſelf: none of its inherent particles can be removed, and the attractive force can operate only at one of two places, either by immediately attracting to the ſurface, where it exiſts, the due quantity of the fluid, or by accumulating the ſame quantity at the oppoſite ſurface, provided the intervening thickneſs does not remove it to a diſtance which the attracting force cannot reach.

FIG. XI.

In ABCD, the black ſpots repreſent the electric fluid; the ſmall circles the integrant particles of the electric.

If the black ſpots be taken away from the circles lying in the direc-

tion of c, f, it is obvious that thoſe circles will be in force to act upon the ſpots in the direction of b, e, which will give way, provided the force, by which they are attached to their adjoining circles, be leſs than the force of the circles which attract.

The ſame changes will take place under ſimilar circumſtances, between b, e, and a, d; and ſo on, ad infinitum, or to the utmoſt extent of that body whoſe peculiar property is that which I have juſt deſcribed.

But when the ſpots in the line c, f, are removed, if thoſe in the line b, e, are too ſtrongly attached to be diſplaced, then it is obvious

that the force, cauſed by the abſence of the ſpots, will continue active, till a ſupply is brought within the limits of its influence, at the ſurface BD, or at the ſurface AC. At BD, the fluid may come immediately into contact with the attracting ſurface; but at AC, it cannot be brought nearer than a diſtance meaſured by a, c.

I. From the explanation I have given, we may learn to qualify the general aſſertion, "that a body cannot contain more than its *natural* ſhare of the electric fluid;" and we may likewiſe furniſh ourſelves with reaſons in confirmation of it, in its qualified ſenſe, additional to thoſe which are derived from experience.

When the body is charged, the force of the circles, in the line c, f, acts at a greater diſtance than it does while the body is in its natural ſtate, and therefore muſt be diminiſhed; whereas it ought to be increaſed, in caſe more fluid was collected at AC, than had been previouſly loſt at BD.

There are caſes in which a quantity of fluid is, as it were, let looſe, and reſts, apparently uncombined, on the ſurfaces of electrics. That part of a glaſs cylinder, which has been recently ſeparated from its contact with the rubbing ſilk, is thus covered; but the circumſtances of this fact are very different from thoſe of a charged electric. The ſurface of the glaſs

cylinder, oppoſite to that on which the fluid is collected, is not at all affected, or, when examined by the moſt delicate teſt, ſhews no ſigns of negation.

It has, in connexion with the preceding aſſertion, been ſtrenuouſly maintained, "that no negative ſurface can exiſt without a correſpondent poſitive." This cannot be true; for that part of an electric, which has been excited negatively, is preciſely in this ſtate juſt after it is ſeparated from the rubbing ſubſtance. This may be at any time proved by examining the ſurface oppoſite to that which has been excited. Indeed, ſigns of negative electricity may be diſcovered on the ſurface of an

excited ſolid, or where it is impoſſible that a correſpondent poſitive ſhould exiſt.

The *general aſſertion*, then, "that an electric can contain no more than its natural ſhare of the fluid," muſt be confined to charged bodies, or to ſuch as are capable of having deficiency exiſting in one part, or on one ſurface, ſupplied by a communication with the other.

II. From the explanation I have given, the progreſs of changes which takes place, while any electric is charged, may be eaſily conceived.

While the rubbed parts are together, a ſtrong attracting force is

in action, which collects a quantity of fluid from every connected ſubſtance, whoſe adheſive force is inferior to that which attracts.

If no other connexion exiſts than between the cuſhion and the air ſurrounding it, then no more fluid can be collected, than what that portion of air can yield from its natural quantity. Let the ſurface of the cuſhion be enlarged, then a greater quantity of fluid will be collected; but let the ſurface of the cuſhion be connected with that of the whole earth, and the friction will then operate upon an exhauſtleſs ſtore, and of courſe every limit to its effects be removed.

When the rubbed parts are ſeparated, the accumulated quantity

of electric fluid reſts on the ſurface of the glaſs, and readily forms a poſitive in one part of the atmoſphere, correſpondent with the negative, which the friction muſt have previouſly cauſed in another. If, when this change has taken place, one ſurface of the electric, to be charged, be brought into contact with the poſitive portion of the air, there is then no attractive force active to produce any change; but let one ſurface be connected with the poſitive portion of the atmoſphere, and the other with the negative by conducting ſubſtances, then the ſuperabundance of one part of the atmoſphere, in contact with one ſurface of the electric, enables that portion of the atmoſphere, which is deficient, to ſup-

ply itſelf from the natural ſhare of the oppoſite ſurface of the electric.

EFGH, Fig. XII. repreſents a body of the atmoſphere loaded with an aditional quantity of the fluid.

ABCD, the correſpondent negative. It is clear that the fluid, contained in EFGH, is kept in its ſituation by the attractive force, which is rendered active by the deficiency at ABCD, and that the inſide of the glaſs jar I, in contact with it, cannot operate; for in its naral ſtate, its force cannot be equal to that of the negative, ABCD; but as ſoon as you connect its outſide, K, with ABCD, the inſuffi-

ciency in that portion is ſupplied the more eaſily, in proportion to that diminution of the attractive force at K, which is cauſed by the nearneſs of the ſuperabundant fluid, and by the contemporaneous operation of the deficiency at ABCD.

Analagous to this ſeries of changes, which takes place between the different portions of a charged atmoſphere and the oppoſite ſurfaces of an electric, are the appearances of two electrical jars, connected with each other.

Fig. XIII. AB repreſents a coated jar, connected with another, BC, by the wire B, which is faſtened to the outſide of the upper and the inſide of the lower jar.

When any quantity of the fluid is introduced at A, a quantity equal to it paſſes from its external ſurface B to the inſide of the lower jar, where an accumulation is formed, and a proportional quantity is ſeparated from the ſurface D.

Though the deficiency at B is in connection with the ſuperabundance at C, it cannot be ſupplied from it; for the attractive force at B is exerciſed upon the quantity accumulated on the correſpondent inſide ſurface A of the ſame jar; and moreover, the accumulation, with which it is in contact, is kept there by the attractive force at D.

But if you connect, by a metallic rod, GH, the poſitive at A,

with the negative at D, then an opportunity is given for the attractive force at B to operate upon the accumulation at C; for this power is releaſed by the contemporaneous action of the negative at D, upon the poſitive at A: a diſcharge, therefore, of both jars takes place at the ſame inſtant, and experiments prove, what might be inferred from the general explanation I have given, that this diſcharge has the force only of one jar.

Let the jars be ſeparated from each other by a ſmall interval of air at E; and while the fluid, in paſſing from A to C, appears luminous at D and H, the fluid, in paſſing from B to C, will appear

luminous in the above-mentioned interval E.

I have taken ſome pains to convince you that the operation of an attractive force alone is ſufficient to account for all the phœnomena of charged electrics---becauſe my ideas on this ſubject are very different from thoſe of Dr. Franklin, who has adopted a theory which, in my opinion, is expoſed to inſuperable objections.

He ſuppoſes that glaſs has wider pores at its ſurface than near its centre, and that the ſmallneſs of the pores near the centre will not admit the particles of the electric fluid, which he conſiders as too large to paſs through them. The

fluid, therefore, is accumulated at the ſurface, and there exerciſes a repulſive power on the particles which are attached to the oppoſite ſide."

The exiſtence of different ſized pores in the glaſs is gratuitouſly aſſumed, and in caſe it was admitted in the ſingle caſe of glaſs, yet in other caſes it cannot be even ſuppoſed without the groſſeſt abſurdity. The inſtance taken from the power of charging the thinneſt lamen of talc, is ſingularly ſtrong againſt this theory, as its ſurface and centre are ſo near each other, as to preclude all ideas of difference in the ſize of their pores.

Beſides, how does this theory account for a ſuperabundance and correſpondent deficiency in two contiguous plates of air? This is a caſe in which no contraction of pores can exiſt to prevent the immediate reſtoration of the equilibrium.

I cannot eaſily grant the repulſive power of the particles aſſumed in this theory. There is no other fact in electricity which may not be readily accounted for without the aid of this power; and in the preſent caſe, if what I have ſaid be admitted, there is no neceſſity of having recourſe to its operation. I would add, that the ſtrong attraction of the negative to the accumulation on the poſi-

tive ſurface, is admitted by Dr. Franklin. Indeed it is impoſſible, on any other principle, to account for the adheſion of the ſuperabundant particles to the glaſs; for if the ſurface neareſt theſe particles has loſt none of its natural ſhare, then, from what I have ſaid, it can have no influence on the particles alluded to. The attraction of the negative ſurface is, therefore, alone active in this caſe; and when ſo much is granted, where is the neceſſity of a repelling power to account for the effect in queſtion? for if the whole glaſs can contain a certain quantity only, when an addition is made to one ſurface, that which adhered to the other muſt readily go off to ſupply

a deficiency that is formed elſewhere.

III. The principles which I have endeavoured to explain and to eſtabliſh, furniſh us with an obvious reaſon for the power of the diſcharging rod. Conductors, you ſhould remember, make little or no reſiſtance to the paſſage of the electric fluid. The attraction of the outſide of the glaſs, to the fluid collected on the inſide, diminiſhes in proportion as the thickneſs of the glaſs increaſes, or the diſtance between the accumulation and the part which attracts it. When, therefore, you connect the outſide and the inſide of a phial by a metallic rod, you do nothing more than annihilate all diſtance between the body which attracts and that

which is attracted. I will explain myſelf by a figure.

FIG. XIV.

A, repreſents a particle of the electric fluid, which is kept in its ſituation by the attraction of the glaſs at B. It is prevented from paſſing to B by the reſiſtance of the intermediate glaſs. But the body of metal, CAB, is a conductor, and makes no reſiſtance to the paſſage of the fluid: conſequently the ſurface, B, when the metallic connexion is formed, muſt operate with full efficacy on the particles at A; as in the direction of CB, all reſiſtance is equal to nothing: in other words, the effect is the ſame as if the thickneſs of the glaſs were at once annihilated.

IV. Let us now ſee how, from the principles already admitted, the action of the metallic coating may be explained. It has been already obſerved, that without the coating no inſtantaneous diſcharge can be made. If, however, you can imagine a metallic diſcharging rod at the ſame inſtant to touch every particle on both ſides of the glaſs, you muſt conclude, from the method of reaſoning uſed in the laſt article, that every particle of the accumulated fluid would be diſcharged at once. The metallic coating operates like ſuch a diſcharging rod; for when both coatings are connected by a good conductor, the ſame opportunity is given for every particle to be influenced by a more powerful ope-

ration of the negative ſurface, than can be exerted through the medium of the glaſs.

V. We have hitherto applied our principles only to glaſs and other ſolid electrics. Air is capable of ſhewing appearances in moſt reſpects ſimilar to what we have been explaining: there are, however, ſeveral obvious varieties; but the leading circumſtances, to which I would call your attention, are the following:---That a certain body of air is capable of being divided into two portions with regard to electricity; the one of which has a ſuperabundance, and the other a correſponding deficiency; that the quantity, however, contained by the whole, is always

the ſame; that the equilibrium between the two portions may be reſtored, when a metallic communication is formed between each particle in the poſitive, and each particle in the negative portion; that the air is alike impermeable to the fluid with glaſs and other electrics, and that there is an intermediate part between the poſitive and the negative, which retains only its natural ſhare.

The foregoing particulars are all founded in ſuch facts as are nothing more than a repetition of the experiments which I have deſcribed as belonging to the Leyden phial; with this difference only, that, in the one caſe, we uſe glaſs; in the other, two plates of air;

which, by the uſe of a certain apparatus, are as eaſily charged as the oppoſite ſurfaces of a Leyden phial. Indeed, the phœnomena of the common conductor are the conſequences of ſuch a proceſs: this will appear, if we attend to that explanation of them which I ſhall now give.

Conceive of any conductor, as ſurrounded by an atmoſphere, containing a ſuperabundance of the electric fluid: to this atmoſphere there muſt be ſomewhere a correſponding atmoſphere in a negative ſtate. The ſmalleſt of ſuch atmoſpheres muſt, in moſt of its parts, be of ſo much extent as to touch the ground. A diſcharge, therefore, of the air ſurrounding the

conductor cannot take place, till a connexion is formed between it and the ground, which, in this caſe, operates exactly like the coating of a Leyden phial. The chief difference between air and ſolid electrics is, that no part of the accumulation penetrates the latter; but the whole ſuperabundance of the electric fluid in air is mixed with the particles of air, and cauſes a ſeparation of them. On this circumſtance depend ſeveral of the ſingularities which belong to what is commonly called the electric ſpark. However, before theſe can be accounted for with any plauſibility, it is neceſſary that I ſhould previouſly call your attention,

VI. To the explanation of a

fact which frequently takes place in the Leyden phial, and which takes place likewiſe between the poſitive and negative portions of air, whenever a ſpark ſtrikes from the conductor to a metallic ball, placed at ſome diſtance from it, and connected by a good communication with the ground,---I mean now to give you, if I can, ſome idea of the cauſe which operates when the interval, dividing the poſitive from the negative ſurface, is perforated. It has been already ſhewn to you, that the accumulation is ſeparated from the deficiency by a portion of glaſs, which retains its natural ſhare with ſuch a degree of attraction, as not to be overcome by the power which acts at the negative ſurface. From

this propoſition, it is a neceſſary corrolary, that when the power at the negative ſurface is ſo much increaſed, as to overcome the adheſion of its natural ſhare of the electric fluid to the intervening glaſs, then the glaſs will ſhew the uſual effects attending the loſs of what enters into any body as a conſtituent ingredient.

Fig. XV. If, by the accumulation at AB, ſo much is driven off from CD, as to enable it, by any means, to take a portion of its natural ſhare from EG; we are then, I think, to expect the conſequences I have already mentioned. Now the principal queſtion in the preſent caſe is the following:---When is the attraction at CD likely to overcome the adhe-

ſion of its particles to EG? I anſwer, that the effect muſt be early or late, in proportion to the power by which the particles adhere to EG. The attractive force at CD evidently increaſes as the accumulation increaſes at AB. I ſhould therefore conclude, that different electrics will require greater or leſs accumulations before they are perforated.

This concluſion is agreeable to experience, as well as to theory. But it may be aſked, Is not the whole power of CD exerciſed upon the accumulation at AB? How, therefore, can it operate on the particles of the interval EG? I anſwer, that the particles at EG are neareſt to CD, and conſequently would be the firſt to unite

with CD, if it were not for a *different power* which operates, and which is no ſooner conquered by the increaſe of CD's attractive force, than the particles are immediately removed, and followed by the particles accumulated at AB.

Fig. XVI. Suppoſe b to be a particle of matter within the ſphere of a's attraction, let c, d, be two other ſimilar particles of matter, nearer to a, and conſequently more ſtrongly attracted, but faſtened by a cement or any adheſive ſubſtance, which has only a certain degree of power; b, if moveable, will be drawn towards a, nor would the other two particles c, d, be removed till a's attractive power was greater

than the adhesive power of the cement. As soon as this happened, then c, d, would immediately quit their situations, and b would come into contact with a.

If you will admit the steps of the preceding rationale, you must conclude, that to accelerate a perforation through glass, or any other electric, nothing is necessary but to confine the accumulation as much as possible to one point; for the larger the surface which any accumulation is spread over, the more must be expelled from the opposite surface, and consequently the longer will you be, before you reduce it to that state of negation, in which the attraction of the internal parts of the glass will yield their natural share.

I will explain my meaning thus: Suppoſe a ſurface of twenty feet received an accumulation, which I eſtimate at 5000; if 7000 were all it could bear, or were all which the outſide could part with, it is evident that this accumulation, reduced to ten feet ſurface, would burſt through the glaſs; for in that caſe the oppoſite ſurface would loſe 10,000, which is 3000 more than it could part with.

FIG. XVII.

EXPERIMENT. Charge the phial, ABCD, as high as it can bear; bring EFGH, which is ten times leſs than it, within its circuit. If a metallic communication be inſtantaneouſly formed between A

and E, and G and D; provided the neck of the ſmall phial be ſo long as to prevent the charge from paſſing over the uncoated part of the glaſs, an exploſion will take place, and the ſmall phial will burſt. In this experiment, it is obvious, that by the inſtantaneous accumulation made on the outſide of the ſmall phial, its inſide is ſuddenly brought into that ſtate which I have already deſcribed as neceſſary for the perforation of the glaſs.

FIG. XVIII.

Exp. I would now produce a very ſtriking fact, ſimilar to the preceding, in which the glaſs is not coated, and in which a very ſmall accumulation, becauſe it is confined

to a ſingle point, forces ſo much off the oppoſite point, as inſtantly to perforate the glaſs. ABCD repreſents a phial filled with oil; e is the point of a wire touching the inſide of the phial; f is the point of a wire placed exactly oppoſite to e, and communicating with the ground. A ſpark, paſſing from the conductor G to the ball A, will immediately ſtrike through glaſs. A conductor, in length one foot, and in diameter three inches, charged by a cylinder not exceeding four inches in diameter, will produce this effect in glaſs whoſe thickneſs equals one-eighth of an inch. The deſign of filling the tube with oil, is to prevent the accumulation from ſpreading, which would be the caſe if the oil, as a non-conductor, did not prevent

the effects of that coating of moiſture, which would otherwiſe adhere to the ſides of the glaſs. The oil is unneceſſary, if you uſe talc or any other very dry electric. By ſubſtituting at e, inſtead of the point, an inch ſquare ſurface of tin foil, and an equal ſurface on the oppoſite ſide, you will find it neceſſary to increaſe the number or the ſize of the ſparks before you acquire the accumulation neceſſary for breaking the glaſs. As the glaſs becomes thicker, the accumulation muſt, for many reaſons already enumerated, be increaſed. A ſmall Leyden phial may be made, by this means, to ſtrike from one point to another through glaſs three-eighths of an inch in thickneſs.

A fact, which at first sight appeared both to my friend Mr. Brook and to myself very puzzling, is, I think, easily accounted for in a manner similar to the preceding. He coated the inside of a phial with cement, and the outside with tin foil. A wire, which touched the cement, was applied to a charged conductor, and the phial at the point of the wire was instantaneously broken. In this case the accumulation is confined to one point, and therefore produces the described effect. I found that if the phial were coated on the inside with cement, and then covered with tin foil, that the usual charge and discharge would take place without any attendant fracture.

I proceed, however, to another concluſion, which the principles and facts, already enlarged upon, render (in my opinion) very probable. It is evident, I think, that when the glaſs or electric is thickened beyond a certain limit, the particles on one ſide may be removed to ſuch a diſtance as to have no attractive influence on whatever accumulation may be made on the oppoſite ſide. This is the cauſe of our inability to charge a very thick phial, and this is the cauſe why glaſs of a certain thickneſs cannot be perforated by any force, if applied as in the preceding experiments.

FIG. XIX.

Expt. Let ABCD repreſent a ſurface of plate glaſs, about four inches ſquare; bring the point of a wire, connected with the inſide of a charged jar, to touch the glaſs at the point E. Let a point on the under ſurface of the glaſs, directly oppoſite to E, be touched by another wire connected with the outſide of a charged jar. To prevent any moiſture from conveying the electric fluid over the ſurface of the glaſs, I have always buried it in oil, or ſome reſinous fluid; and in making experiments upon it, thus circumſtanced, I have obſerved,

1ſt, That I could never make the higheſt charge ſtrike through a thickneſs of glaſs exceeding four-tenths of an inch.

2d, That when I uſed points, it made no difference whether I applied the force of one or ten quart jars; the effect was always the ſame.

3dly, When ſurfaces, of different dimenſions, of tin foil, were placed in the ſituation of the point, then, as the ſurface of the tin foil increaſed, ſo was the number of jars increaſed, which were neceſſary to perforate the glaſs.

The greateſt ſingularity obſervable in the preceding facts is, I.

think, eaſily elucidated. You ſee that ten phials would not ſtrike through a greater thickneſs of glaſs than one. The perforation (as we have already ſhewn) depends upon our forcing, from a particular portion of one ſurface, a certain quantity of electricity. But this cannot be done if the glaſs be ſo thick as not to allow the negative to approach ſo near the poſitive as to exerciſe its attractive force.

The facts in which a battery appears to produce a greater effect on electrics, than a ſingle phial, are thoſe in which the firſt principles, already applied, very frequently would lead us to expect ſuch effects. I will enumerate a few of them.

Fig. XIX. If the accumulation at E be confined to a point, it is evident that the oppoſite point can afford but a very little loſs before a perforation takes place. If the ſurface at E be increaſed, to bring the oppoſite ſide into that ſtate in which the perforation takes place, a greater accumulation of the electric fluid is neceſſary: nay, the ſurface may be increaſed, ſo that the contents of a large battery would be neceſſary. Thus now, if the ſurface at E be one-eighth of an inch, and if twenty particles are to be forced off the outſide previous to the perforation, it would make no difference whether you accumulated forty or twenty on the oppoſite ſide; for in both caſes the cauſe would be adequate

to the production of the effect. If the ſurface be increaſed to one-fourth of an inch, then to produce the perforation, an accumulation of forty particles would be neceſſary. If the ſurface be half an inch, then eighty particles would be neceſſary, and conſequently four times the charge would produce the perforation of one-eighth. Theſe ſpeculations are very much confirmed by the facts which I have ſhewn to you, and from which, indeed, I originally deduced them.

But again, the principles I have enlarged upon, have ſufficiently explained to you the reaſon why the charge of a *jar* paſſes more eaſily from a point than a ſurface.

With very little exertion of mind we may apply the ſame reaſonings to the quick diſcharge made by a point of an electrified body of air, and to the inſulating power of a ſurface or ball of a certain magnitude. I muſt recur to a figure (Fig. XV.) which I have uſed before.

Suppoſe AB and CD to repreſent the negative and poſitive portions of air which is charged; it is evident, from what I have already ſaid, that every part of the ſurface, CD, muſt be deprived of a certain portion of the fluid, before the accumulation at AB can force its way through the interval EG. It muſt, moreover, appear, in caſe the ſurfaces were perfectly flat and oppoſite to each other,

that before the perforation can take place, a loſs muſt be made at CD, which would be great in proportion to the area of its ſurface; and unleſs an inequality in the reſiſtance made by the interval, EG, ſhould produce a diſcharge, the accumulation muſt be continued at AB, till every part of EG gave way at the ſame inſtant; for while the ſurfaces are alike, the influence of the attractive power at each particle, g, in the plate of air, upon each particle, h, muſt be equal, and previouſly to the diſcharge, the reſiſtances made at all the ſeveral intervals, from g to h, are to be overcome.

Now let one of the lines, gh, be ſhortened, while all the reſt con-

tinue the ſame; or let a metallic point be carried out to e, and then the whole attraction at CD muſt operate in the direction eh, and muſt produce that ſtate in which the fluid paſſes through a non-electric to ſupply the negative ſurface, while any accumulation continues at AB. Now if this account of the fact be admitted as true, you will, I apprehend, immediately perceive why a point extending no further than the ſurface of the conductor, though it be in the middle of a cavity, has no effect; for in that caſe, what is repreſented by gh, is not ſhortened. I have no doubt that one difficulty ſtill preſſes upon your minds. I mean that of explaining how the whole attractive force operates inſtanta-

neouſly at ge. I think a ſingle experiment will remove your difficulty.

Fig. XX. Let A, B, C, &c. repreſent ſo many diſtinct portions of electric ſurfaces charged poſitively; G, H, I, &c. their correſpondent negative ſurfaces. As ſoon as you ſupply the deficiency at G from A, by a metallic rod, G will take a new charge immediately; for the negation at H is inſtantaneouſly divided between it and G, and the accumulation at B is inſtantaneouſly divided between it and A, and the ſame diviſion between C and B, and I and H. Now by diminiſhing the dimenſions of each little ſuperficies, and multiplying their number, you come at once to the difficulty in queſtion.

The operation of the metallic rod is ſimilar to that of diminiſhing the diſtance gh, in Figure XV. and if the portions, A, B, &c. repreſent ſingle particles, the modes of operation which I have pointed out, muſt take place a fortiori.

But again, it muſt appear to you in this caſe, as in others which I have made uſe of to explain the reſiſtance of glaſs, that in placing a ſmall ſurface, inſtead of the point e, (ſee Fig. XV.) you increaſe the intervening reſiſtance of e, h; and hence is clear the reaſon why balls of different dimenſions inſulate more or leſs, becauſe their ſurface will increaſe in a certain proportion to their dimenſions. The prin-

ciples upon which I have amplified might be applied to a multitude of known facts, which will occur to you, if you be ambitious after any degree of experience in this ſcience.

I will, however, call your attention to one fact more, and that is the ſuperiority of length in the ſpark yielded by ſhort conductors of a large diameter, to that of a ſpark yielded by conductors of a great length and ſmall diameter. We ſee, in the caſe of the Leyden phial, that in proportion to the accumulation on any given ſurface, ſo will the thickneſs of the glaſs be through which the perforation is made.

The ſame effects follow, when the accumulation is made in a body of air ſurrounding a common conductor, and conſequently the ſame difference takes place in the interval of air through which the charge paſſes; that is to ſay, the larger the body of air, through which any given quantity of the electric fluid is diſperſed, the larger will the ſurface be of the correſpondent negative. Vice verſa, As you diminiſh the body of air, you heighten the charge, and increaſe or magnify its effects. But it is clear, that when you lengthen your conductor, you increaſe that quantity of air which you charge, much more than when you increaſe the diameter of it. To be convinced of what I have now advanced, we

need only caſt our eyes on the figures repreſenting Volta's rods and Brooks's gridiron: in both theſe inſtances, the apparatus is ſo formed as to conduct the fluid over an extent of atmoſphere, to which, when compared with it, the atmoſphere ſurrounding a conductor three feet in diameter, and eight feet long, is trifling.

It is time I ſhould once more quit the region of ſpeculation and theory, and return to the enumeration of plain facts.

ON THE ELECTROPHORUS.

The facts I have hitherto deſcribed, and enlarged upon, were the conſequences of two very ſimple additions to our apparatus.

You have as yet known nothing of electricity, beſides the numerous effects of placing, either a common conductor, or a Leyden phial, near your cylinder, ſoon after, or during the friction of it. The aſtoniſhment of electricians has been very much awakened lately by that diſcovery of Signior Volta's, whoſe appearances I ſhall now diſplay, and hereafter endeavour to explain.

FIG. XXI.

A is a round plate of braſs, copper, or wood, covered with tin foil, and carefully freed from all edges and points. To this plate Signior Volta has given the name of ſcudo.——B is another round plate of wood or braſs, or,

indeed, any other ſubſtance covered with a varniſh. Some prefer a cake of ſulphur; others, a coating of ſealing-wax, diſſolved in ſpirits of wine; and others, a coating of roſin, diſſolved in oil of turpentine. To the upper plate is annexed a ſtem of glaſs, or of ſome other non-conducting body. The appearances which depend on the uſe of this apparatus are the following:

If the ſurface of the lower plate be well dried, and then rubbed till it ſhews ſigns of electricity; and if in this excited ſtate, the ſcudo be placed upon it, connected at the time by any conducting ſubſtance with the ground, let the connexion with the ground be ſuddenly broken,

and the ſcudo raiſed by the aid of the glaſs handle or ſtem, and ſeveral curious effects may be obſerved.

1ſt, A ſpark will ſtrike to any conducting body, which is brought near the ſcudo.

2d, The ſcudo will always be found in a ſtate oppoſite to that of the excited plate, (i. e.) poſitive when the plate is negative, and negative when the plate is poſitive.

3d, If the ſcudo, after emitting a ſpark, be placed on the plate again, and again connected with the ground, and raiſed by the handle, the ſame appearances will be diſcovered without the aid of

any freſh excitation; nay, the repetition of this proceſs may be made for hours together, without any ſenſible difference of effects, provided the apparatus be kept perfectly free from all accidental moiſture, feathers, hairs, duſt, and other light ſubſtances which float in the air of almoſt every room.

4th, If the ſcudo touch the electric in a few points only, a conſiderable ſpark may, notwithſtanding, be drawn from it, by proceeding as I have already deſcribed.

5th, The force of the electrophorus, when much weakened, is ſaid to be very much increaſed by placing a charged phial on the lower plate, and by gradually diſcharging

at one ſurface, while the other is in contact with the excited ſurface of the electric. The ſame effect is ſaid to be produced by conveying the ſtrong charge of one ſcudo into that of the electrophorus, which is weakened.

Hitherto we have had no other rational attempt to explain the phœnomena of this curious inſtrument, than that made by my excellent friend Mr. Bewly, in the Monthly Review; who ſays, "that the excited plate acts upon the electric matter naturally contained in the upper braſs plate, and repels from it a part of its natural quantity, in the form of a ſpark, at that part where the finger is applied to it. If (ſays

he) the braſs plate, in this ſtate, is lifted up by its handle, it will receive a ſpark from the finger." The repetition of this effect he aſcribes to the retention of its virtue by the electric, which does not loſe any of its own electricity. This mode of explaining accounts only for the electricity where the excitation produces poſitive electricity: the explanation muſt be reverſed in the caſe of negative electricity; but it is expoſed to objections, which ſtrike me as inſurmountable: 1ſt, It calls in the aid of a repellent power, where I think it is not at all neceſſary, and previous to any deciſive proof of the operation of ſuch a power in this ſcience. 2dly, I object to the repulſion or attraction of electric matter from the SCUDO. This

language is inaccurate. The ſcudo operates only as a conductor, and the whole effect is the conſequence of a ſurplus or deficiency in the air ſurrounding the ſcudo.

By attending cloſely to the ſingularities of the electrophorus, you will be led, I think, to agree with me in conſidering it as differing from the common cylinder in one circumſtance only, and as owing its effects to the very ſame cauſes, by the aid of which we have already accounted for the operation of every other electrical machine. The ſimilarity of the inſtruments will appear by attending to the following particulars:

1ſt, An inſulated cuſhion, covered with tin foil, and applied to

the cylinder, will ſhew all the appearances of the electrophorus.--- The experiment I allude to, I would deſcribe thus; Fig. XXII. AB is a piece of wood made hollow, and perfectly free from all edges and points: it is covered with tin foil, and inſulated by the glaſs ſtem CD; a cuſhion is placed in it, and employed agreeably to the common mode in exciting the cylinder EF. No electrical ſigns, however, will be diſcovered, while the inſulation CD is complete, be the cylinder turned round ever ſo frequently: but if you ſtop the motion, and place your finger upon AB, and then remove AB from its contact with the glaſs, on the application of your knuckle, AB will yield a ſpark, if brought in

contact with the glaſs a ſecond, a third, and a fourth time, without turning the cylinder, or repeating the friction.

By a proceſs, ſimilar to what I have already deſcribed, repeated ſparks may be obtained, with all the circumſtances attending them, which we have deſcribed as the effects of the electrophorus. Now by placing a glaſs plate in the room of EF, and by ſuppoſing AB to cover the whole plate, you form an electrophorus without producing one ſingle circumſtance of diverſity from the common cylinder. But again, if after you have excited the electrophorus, you take away the ſcudo, and apply a number of metallic points connected

with the ground, to the excited ſurface, and then apply the ſcudo, no more ſparks can be obtained without a freſh excitation. This is exactly ſimilar to what takes place in working with the cylinder; for, as ſoon as the excited part has paſſed the cuſhion, a multitude of points are applied to it, which reduce the excited part into its natural ſtate, and render it incapable of ſhewing electrical ſigns till it comes again into contact with the cuſhion. Once more, if the ſurface of the electrophorus be excited, and metallic points be applied to it, connected with an inſulated conductor, the conductor will be diſcharged juſt as it is when applied to an excited cylinder.

I need not, ſurely, amplify any longer on the ſimilarity of an electrophorus to a common machine, or on the poſſibility of making the latter ſhew all the phœnomena of the former. I ſhall now beg your attention to thoſe effects, which made this inſtrument, when it was firſt diſcovered, appear ſo wonderful, and ſo different from all others.

Why, without any freſh excitation, does the application of the ſcudo, and the finger in the electrophorus, and the inſulated cuſhion in the caſe of the cylinder, yield *repeated ſparks?* You may remember, that I have already aſcribed the ſeparation of the fluid from electrics, to that change of

attractive power which neceſſarily takes place when bodies, different in their nature, are brought into cloſe contact. In the preſent caſe you may ſee the operation of this cauſe, by attending progreſſively to the various ſteps obſerved in exciting the electrophorus.

The hair ſkin, the ſilk, or any other body, which you employ as a conductor, is brought into perfect contact with the ſurface of the electrophorus. In this ſtate the bodies attract more or leſs, united, than they do ſeparately; conſequently, a portion of the fluid is taken from, or conveyed to the earth through the hand, or whatever elſe is connected with the rubber. Let the hair ſkin be ſe-

parated from the ſurface of the electrophorus, and that ſurface will either have a quantity accumulated, which it is ready to part with, or it has loſt a portion, which, when the rubber is removed, it will be eager to attract from any approaching body. In other words, you will find the excited ſurface either in a poſitive or negative ſtate. Let us firſt conſider it in a poſitive ſtate.

By placing the ſcudo on it, thus circumſtanced, why does not the ſcudo yield a ſpark on the approach of a finger to it? or immediately convey to any conducting body, which is near it and connected with the earth, the ſuperabundant fluid which is accumulated

on the ſurface? I anſwer, that as ſoon as you bring the ſurface of the metal into contact with the excited poſitive ſurface, the law of attraction is immediately altered. The two ſurfaces attract more than either would ſingly, and are not only able to retain all the ſuperabundant fluid on the excited ſurface, but to take more, which is evident from experiment. When, however, you remove the ſcudo, the union which cauſes a ſuperior attraction is immediately diſſolved, and there is nothing to prevent the accumulated ſuperabundance from ſtriking out of it in the form of a ſpark.

It may be aſked, why, if this theory be true, is it neceſſary to

rub the ſurface of the electric, before its contact with the ſcudo produces the effect in queſtion? I ſee no abſurdity in ſuppoſing that the attraction I have alluded to ſo frequently may be helped by an accumulation of the fluid on the ſurfaces, juſt as a ſmall drop of water or oil, expanded on their ſurface, promotes the adheſion of two pieces of glaſs. Beſides, the rubbing, when employed, operates in a variety of ways favourable to the excitation. But again, in ſupport of the hypotheſis I have given, obſerve, that this is not the only inſtance in which the union of a ſurface of metal, with that of an electric, produces electric appearances. Our amalgams operate on this principle, and I have al-

ready enumerated ſeveral other ſimilar facts; to which may be added, a very deciſive experiment made by Mr. Bennet. He heated a well poliſhed marble plate, ſo as perfectly to free it from all moiſture. He then placed upon the ſurface a braſs plate ground, which he preſſed cloſe to the marble with a metallic rod. When the braſs plate was ſeparated, it gave evident ſigns of the additional fluid, which had been collected by its ſimple contact with the metal.

The reverſe of the caſe which I have juſt now explained, muſt be obvious to you. If the two ſurfaces, when joined, will take leſs than during their ſeparation, by their union they will loſe a certain

quantity, and in the act of losing will give signs of positive electricity. But I shall recur to the explanation of this and other similar appearances, when I have described the effects of

THE INSULATED ELECTROPHORUS.

FIG. XXIII.

AB is a rounded piece of wood, covered with tin foil, and resting on an insulating stand, CD. On the surface of AB is to be placed the excited plate: ab, is a wire with a brass ball, to which are appended the pith balls g and h.

1st, After the hand has been laid on the scudo in contact with

the plate, not the leaſt ſigns of electricity are diſcoverable on the removal of the ſcudo.

2d, If both ſurfaces of the excited plate be connected by an inſulated metallic diſcharging rod, and if the ſcudo be afterwards raiſed; in this caſe, again, no ſigns of electricity will be diſcovered.

To ſucceed in this experiment, the reſinous plate ſhould be completely freed from all points; and before the junction of the ſcudo, every part of the apparatus, excepting the excited ſurface, ſhould be carefully purged of all adhering electricity.

3d, The ſcudo is *then* only

charged, when the communication between itſelf and the plate is continued to the ground; but the pith balls, during this proceſs, do not ſeparate, till the ſcudo is raiſed: in conſequence of the elevation, they ſuddenly diverge, and when the ſcudo, *undiſcharged*, is put down again upon the plate, they inſtantly cloſe; but when the ſcudo is *diſcharged*, and then placed on the excited ſurface, the divergence is continued.

In this ſituation, by forming a connexion between the upper and lower ſides, a ſmall charge is communicated, which grows leſs and leſs with each repetition of the proceſs.

4th, A ſpark, after the ſeparation, may be taken from the braſs plate, nearly as powerful as that which ſtrikes from the ſcudo, but always of an electricity oppoſite to that of the ſcudo.

The preceding are ſome of the moſt remarkable appearances of the inſulated electrophorus, when the excitation is that of *friction*. The varieties are numerous, which take place when the excitation is that of communication.

5th, When the negative ſurface of a charged phial is placed on the excited ſurface, by bringing the hand into contact with the oppoſite ſide of the phial, a ſpark is inſtantly communicated, and the

pith balls, g and h, ſeparate negatively.

If the phial be taken off, and the ſcudo placed in its room, no change is obſervable on the ſubſequent removal of the ſcudo, provided, that no communication has been formed between it and the ground. When ſuch a communication is formed, a charge is communicated, and the ſcudo and the balls are in oppoſite ſtates of electricity.

If the poſitive ſide of a Leyden phial be placed on the excited ſurface, the pith balls ſeparate poſitively. You will obſerve that theſe experiments are made with a reſinous ſubſtance.

6th, The appearances of the pith balls and ſcudo are materially varied, if the Leyden phial be applied to the electrophorus while the ſcudo is in contact with its excited ſurface. If the negative ſide of the phial be applied, and a ſpark be taken from the poſitive, the pith balls immediately ſeparate negatively; but, on taking up the ſcudo, they immediately cloſe, and as rapidly ſeparate again poſitively.

If, after the phial is removed, the hand be applied to the ſcudo before it is raiſed, a ſmall ſpark ſtrikes into the hand; but on raiſing the ſcudo, the balls cloſe and ſeparate inſtantaneouſly, and give ſigns of poſitive electricity.—

If the ſcudo and the braſs plate be connected, either by an inſulated or uninſulated diſcharging rod, the balls cloſe and ſeparate again, and the ſcudo, upon being raiſed, receives a vigorous negative ſpark.

It is obvious that in all the preceding experiments, the braſs plate continues unchangeably adherent to the lower ſurface, while the ſcudo only, or the conducting ſubſtance in connexion with the upper ſurface, is immoveable. It is of importance that we ſhould know the conſequences of making both the metallic ſurfaces moveable.

But this is not an eaſy matter; it is very difficult to get a reſinous ſubſtance thin enough, and at the ſame time firm enough, for the

purpoſe. The perfect lamina of talc, which I have been able to procure, are too ſmall to be uſed with any ſatisfaction; I have, therefore had recourſe to glaſs for the purpoſe. The reſult of my repeated trials are the following:

7th, Having ſubſtituted a glaſs plate, about twelve inches in diameter, and one-fourth of an inch thick, in the room of the reſinous ſubſtance, and having reſted it on a ground metallic plate, five inches in diameter, and well connected with the pith balls g and h, I expoſed it to the ſparks of a conductor charged poſitively, and kept my hand at the ſame time in connection with the wire ab. The plate took a conſiderable charge; its upper ſide was unequivocally

poſitive, and its lower ſide negative. I placed the ſcudo on the glaſs thus charged, and, approaching it with my hand, I received a ſpark. I then approached a b with my hand, and received another. By alternate approaches of this kind, four or five times repeated, the ſparks became weaker and weaker, till they diſappeared; the ſcudo was then raiſed, and was ſtrongly negative; but the pith ball, on the removal of the ſcudo, cloſed and ſeparated poſitively.

I then made the lower the upper ſurface, and, placing the ſcudo upon it, formed the communication, as in the preceding part of the experiment; but upon being raiſed, the ſcudo was ſtrongly poſitive, and the balls negative.

But if, previous to the placing of the ſcudo on the glaſs, the pith balls be carefully diſcharged of all adherent electricity, both the upper and lower ſides of the glaſs will be charged with poſitive electricity, or will give ſigns of *their being in the ſame ſtate at the ſame time.*

It is obſervable, that the ſucceſſion of electricities, in the preceding experiments, *ſeems* to vary according to the priority of contact given to the wire or the ſcudo. But though this happens moſt frequently, yet ſuch anomalies take place as not to juſtify us in conſidering this ſingular connexion of diverſities as by any means certain.

The appearances I have juſt deſcribed, cannot be ſhewn on the reſinous electrophorus, in conſequence of its being faſtened to the braſs plate; but, by examining the experiments I have already gone through on this inſtrument, you will ſee ſufficient reaſon for admitting that the very ſame changes would take place if we could introduce the reſinous cake into the ſame circumſtances.

Your recurrence to one leading truth, whoſe evidences, I think, are ſtrengthened by arguing from ſeveral of the appearances which I have juſt now deſcribed, will guide you through an eaſy inveſtigation of the various modes by which all are derived from the

operation of one cauſe. Remember, that the ſcudo is never placed upon, or taken off the excited ſurface, without an attendant diminution or increaſe of attractive force.

When friction or the Leyden phial has communicated a partial charge to the plate Gh, and when the balls, in contact with its lower ſide, are conſequently ſeparated, the ſcudo is no ſooner in contact with the plate, than the balls inſtantly cloſe, and when it is taken off, they inſtantly ſeparate. In perfect conſent with the preceding fact, is the diverſity which takes place in the charge when the reſinous ſurface is excited with the

ſcudo *on*, or the ſcudo *off*. In other words, the introduction of the ſcudo is that of a new power, amongſt whoſe effects are the ſingularities which ſeparate the phœnomena of the electrophorus from thoſe of the Leyden phial.

CASE I.

The ſcudo is placed on the poſitive ſide of the charged plate. Let us now ſuppoſe that when the two bodies are thus joined, an additional force is created, requiring, at the upper ſurface, a certain quantity of the fluid. This quantity cannot be taken from the accumulation of the charge, though in contact with the ſcudo; for the whole affinity of the accumulation

is to the attractive force acting on the negative or lower side of the glass.

The required quantity cannot be taken by forming a connexion with the ground; for before such an addition is made to the upper surface, there must be a contemporaneous removal of an equal quantity from the lower surface.

You hence see the reason why, in the case of the resinous electrophorus, the charge could never be made till a communication was made between the upper surface and the lower surface, and the ground; for, by this means, we not only supply what is wanted, but we at the same time furnish

an opportunity for producing a correſpondent deficiency.

We are now to conceive of the apparatus, not only as having the charge communicated by the firſt excitation, but as having another dependent on the preſence of the ſcudo. Let the ſcudo be raiſed, and the whole additional fluid, collected by its attractive power, muſt be diſengaged, and, conſequently, a poſitive ſpark may be received. The lower ſide muſt likewiſe be negative; for the loſs, cauſed by its firſt excitation, is now increaſed. But recollect, that on raiſing the ſcudo, and by diſcharging the poſitive it cauſed on the upper ſide, you leave a negative

on the other ſide, greater than is anſwerable to its correſpondent accumulation: conſequently, the upper ſide is diſpoſed to receive more, and, though in a different ſtate, ſhews *exactly the ſame ſigns with the lower ſide.*

CASE II.

When the ſcudo is placed on the excited ſurface, let us firſt touch the wire ab, and then form a connexion with the ground and the upper ſurface, a quantity of the fluid is immediately diſengaged on the upper ſurface, which goes to anſwer the additional attractive force cauſed by the preſence of the ſcudo: the remainder paſſes off like a common diſcharge, or it

is diſpoſed of in reſtoring the equilibrium between the two ſides; ſo that the only charge which remains is that which depends on the operation of the ſcudo, which, by having touched the wire firſt, has attracted an accumulation to the lower ſide: when, conſequently, the ſcudo is raiſed, or its power deſtroyed, the lower ſide is poſitive, and the ſcudo negative. But the ſeparation of the ſcudo leaves the negative, on the upper ſide, leſs than what is correſpondent to the oppoſite poſitive; it is therefore diſpoſed to part with more fluid, and, as in the laſt caſe, *ſhews the ſame ſigns of electricity with its correſpondent ſurface.*

I could have ſhewn you many other varieties of appearances which depend on varying the circumſtances of the electrophorus: but I am afraid that a detail, rendered tedious by the endleſs recurrence of the ſame words, and by the frequent neceſſity of provoking the attention to very minute differences, may have excited ſuch ſtrong wiſhes for the introduction of a new ſubject, as are altogether unfavourable to the further inveſtigation of the preſent.

I would, however, obſerve to you, that the knowledge of what I have been ſo long deſcribing and explaining, is eſſential to the character of a good electrician.

When the intricacies of the electrophorus are well conſidered, few caſes can occur, in which the influence of oppoſite ſurfaces may not be eaſily inveſtigated; but when the intricacies of the electrophorus are not underſtood, we are expoſed to the danger of committing endleſs blunders, and ready to conceive of every new appearance as overturning Dr. Franklin's theory, and as juſtifying the fabrication of the moſt abſurd conceits and extravagancies.

THE DOUBLER.

This inſtrument is the invention of Mr. Bennet, to whom we are ſo much indebted for the electro-

ſcope, whoſe advantages we have already ſo frequently experienced.

By the aid of the doubler, Mr. Bennet deſigned to aſcertain the ſmalleſt poſſible quantity of electricity that can be collected. I will now give you his deſcription of its peculiarities, and of the appearances which reſult from its operations.

FIG. XXIV.

The doubler conſiſts of two poliſhed plates of glaſs, A and B, with inſulating handles; the handle of one is fixed on the ſide of the plate, and the other on the centre, where it ſtands perpendicularly to the ſurface. The plates are var-

niſhed on the under ſides only.--- When the doubler is to be uſed, B is placed on C, a plate communicating with the metallic ſtrips of the electroſcope.

The charged ſurface, which you mean to examine, is brought into contact with B, while reſting on C. The finger, or ſome other body in connexion with the ground, is then brought to touch C, and the plates are immediately afterwards ſeparated, and A is laid on B. A connexion is next formed between A and the ground; it is afterwards ſeparated from B, and brought into contact with C. While A and C are together, B is again laid on C, and again touched by the finger. The plates are then re-

moved, and the communicated electricity is expreſſed by the ſeparation of the gold leaf ſtrips in the electroſcope.

Each repetition of the proceſs, I have juſt deſcribed, is ſaid to double the quantity of electricity.

The mode of operation is ſuppoſed, by Mr. Bennet, to be the following:

By the firſt application, the lower ſurface of the varniſh of B participates in the electricity of that firſt charged ſurface which is brought into contact with it; an oppoſite electricity is conſequently produced on the upper ſurface of the varniſh of B, or on that which

is neareſt the braſs plate. When A, therefore, is laid on B, the lower ſurface of its varniſh participates in the electricity of the upper ſurface of B's varniſh, and of courſe is exactly the ſame with that of C, and, when added to it, muſt increaſe it as often as that addition is made.

The preceding illuſtration is not, in my opinion, to be reconciled with the acknowledged principles of the Leyden phial. A is laid on B, and, by the ſimple contact of the finger with the upper ſurface of its varniſh, the lower ſurface of A becomes charged. This you muſt perceive, at firſt ſight, to be altogether impoſſible, unleſs a communication be at the ſame time

formed between the lower ſurface of B and the upper ſurface of A. It is then analogous to the caſe of the two Leyden phials, whoſe oppoſite ſides are connected.

Again, when A is brought near C, with B laid upon it, the charge of its lower ſurface is ſuppoſed to act, not upon its own correſpondent upper ſurface, but upon the upper ſurface of B, which is conſequently ſuppoſed to be doubled in its influence by the contemporaneous action of two oppoſite ſurfaces: whereas the lower ſurface of A cannot act at all, unleſs the charge on its upper ſurface be at the ſame time removed: but by doing this, you deſtroy the very influence which is wanted for the

explanation given by Mr. Bennet; for the negative, which operates as a doubler, owes its exiſtence to that poſitive whoſe removal has taken place.

The idea that the negative of one excited body may be increaſed, by bringing it cloſe to the poſitive of another, is altogether erroneous in every inſtance, but that in which the poſitive has a contemporaneous opportunity of acting, and even in that inſtance it takes place only in a certain degree, and in certain circumſtances.

1ſt, If the poſitive of a charged phial be united with the poſitive of another phial charged lower than itſelf, and their negatives be at the

ſame time connected, then the higher charge will communicate till both are equal. But,

2dly, Though the excited ſurface in one caſe be that of immenſe dimenſions, and in the other that of a few inches only, the vaſt body of electricity in the large ſurface will communicate no more to the leſſer ſurface, than what is ſufficient to bring it into the ſame ſtate of excitation with itſelf. This is clear from the following fact.

Experiment. On the two ſides of a plate of glaſs, twelve inches in diameter, I paſted two pieces of tin foil four inches ſquare; when the contents of a battery of thirty ſquare feet, charged as highly as it

could bear, was *gradually* brought near the tin foil on one ſide, and a connexion took place at the ſame time between the other ſides, the glaſs plate took the charge only of each diſtinct phial in the battery, and the diminution of the whole bore the ſame proportion to the reſidue, as the ſurface of the glaſs plate did to that of the battery.

In the common operations of electricity, you are perpetually witneſſes to effects illuſtrative of the ſame principle. As ſoon as the air in the room becomes damp, or any accidental conducting vapour falls on the ſurface of your working cylinder, however clean your Leyden phials may be, you will

yet find it impoſſible to charge them; for, let the circumvolutions of your machine be ever ſo numerous, the phials cannot receive a higher ſtate of excitation than the cylinder which charges them.

You will hence ſee, that a language which has been lately uſed with ſuch frequency by electricians, as to become almoſt habitual, is altogether improper and abſurd. They are perpetually talking of condenſing the fluid on a particular ſurface. If they mean any thing by the word *condenſation*, they muſt mean that a quantity, which was previouſly ſpread over a large ſurface, is ſubſequently confined to a ſmaller ſpace. In other words, that you may compreſs

forty particles ſpread over two ſquare inches, ſo as to lie on a ſingle ſquare inch. If this be true, then a higher excitation may be cauſed by a lower, in oppoſition to all that I have ſaid; for forty particles on an inch ſquare is poſitive, with a degree of force twice as great as the ſame particles on two inches ſquare.

Briefly, then, my objections to Mr. Bennett's illuſtration of the powers of his own doubler are reſolved into the following:

1ſt, He ſuppoſes charges to be conveyed from one ſurface to another, without a proper communication between the ſurfaces.

2d, He admits, as a principle, the poſſibility of exciting a greater by an inferior power, or that the negative of B is doubled in the height of its charge by a poſitive that is exactly of the ſame height with itſelf.

3d, He ſuppoſes a particular charged ſurface to operate by its ſuperabundance in producing a negative, previous to the removal of its own correſpondent negative.

That the appearances of the doubler are not thoſe of the Leyden phial, will be ſtill more clear, if, inſtead of the varniſhed plates, we ſubſtitute two very thin glaſs plates of conſiderable dimenſions, and make them analogous to the

varniſhed braſs, by leaving one ſide naked, and by coating the other with tin foil. If experiments be thus made on a large ſcale, the impoſſibilities I have alluded to become very obvious.

In my opinion, the doubler is a combination of two electrophori. The varniſhed plate anſwers to the reſinous ſubſtance, and the braſs plate of the electroſcope, with its glaſs cylinder, is exactly ſimilar to a ſcudo, inſulated by a tube, in the hollow of which are appended two gold leaf ſtrips.

When the varniſhed plate is placed on the top of the electroſcope, the application of a charged phial to its ſurface operates as an exciter,

and when the varniſhed plate is raiſed, the cap of the electroſcope, like the ſcudo when removed from an electrophorus, is charged with the electricity produced from the previous junction of the two bodies.

The varniſhed plate, B, has its braſs now charged with a certain quantity of electricity, or with enough to act as an exciter, when the varniſh of A is laid upon it. By the ſimple application of the finger to A, according to our experiments on the electrophorus, no charge ought to be communicated. A connexion ſhould be formed at the ſame time with the braſs of B: but I have found, that when the reſinous ſubſtance is laid on

very thinly, and when great care is not taken to keep the metallic ſurfaces at a proper diſtance, a ſpark will be communicated. In the figure given by Mr. Bennet, of his doubler, the piece of braſs to which his horizontal handle is fixed, neceſſarily produces ſuch a connexion.

The ſpark of A, ſtriking into C, is fully adequate to any increaſe of electricity that can be communicated to the electroſcope.

The appearances which I have endeavoured to explain, are ſeen on a larger ſcale by ſubſtituting, in the room of the varniſhed plates, two electrophori, a foot, or a foot

and a half, in dimenſions. If the reſinous ſubſtance be ſpread over a poliſhed braſs plate, the experiments are then in every reſpect ſimilar, though much leſs equivocal in their language than thoſe of the doubler.

It is to be obſerved, however, that whether I am right in my explanation, or otherwiſe, the doubler, when applied to its intended purpoſe, may be uſed with great confidence: it is meant to *collect* a quantity large enough for the deciſive examination of that very electricity, which is too feeble in its diſperſion to undergo any accurate inveſtigation; and every experiment on the electrophorus proves, that when a charged phial

is brought near enough to ſtrike a ſpark into the ſcudo, the electricity of the applied ſurface will always be the electricity of the ſcudo.

But it is to be remembered, as a conſequence of our experiments on the inſulated electrophorus, that appearances would be altogether different, if the varniſhed plate was not in contact with the braſs plate of the electroſcope, when the phial is applied.

THE MOVEABLE DOUBLER.

This, like the reſt of Mr. Bennet's inventions, is an inſtrument in its effects very important to the ſcience of electricity.

I prefer Mr. Read's improvement of this inſtrument for ſeveral reaſons, but chiefly for the ſuperiority of its inſulations.

FIG. XXV.

ABCD gives one view of Read's doubler. The ſhaded parts of the figure are metal, the unſhaded parts glaſs. A, B, C, are the excited plates, ſcrewed on to the flattened braſs at e, f, g: a, is the ſocket through which the axis paſſes, by whoſe means the braſs plate revolves.

FIG. XXVI.

Preſents another view of the moveable doubler. E is the ter-

mination of the metallic axis. B repreſents the arm upon which the moveable plate is fixed. A and C are the immoveable plates fixed on their bent inſulators. F is a metallic pin, which revolves with the axis, and is connected with M, when the plate B is oppoſite to A. G is a croſs piece of wood or metal, to which a piece of wire, KI, is faſtened, ſo that the whole may participate in the motion of the axis. N is the handle, and is placed ſo as to counterpoiſe the weight of the moveable plate. The different wires muſt be bent, ſo that when F touches M, there may be no metallic connexion between the immoveable plates; but when IK touches M, then the metallic connexion ſhould be complete be-

tween the plates, or the wire IK ſhould at the ſame time touch M and H.

The effects of the preceding inſtrument are the following:

1ſt, When the handle has been turned eight or ten times round, the plates will be found to have collected a quantity of electricity, ſufficiently powerful to be examined by a ſenſible electroſcope. After fifteen or twenty rotations, a ſpark will ſtrike from one plate to another: but the rapidity of this effect will depend on the care that has been taken to inſulate the plates.

2d, The moveable and immove-

able plates may be made either of wood, leather, gypſum, ſal amoniac, ſal prunella, allum, glaſs, or metal, and the nature and the intenſity of the electricity will not vary.*

3d, The electricities of the moveable and immoveable plates are always oppoſite. B is poſitive when A and C are negative; and B is negative when A and C are poſitive. But it is not eaſy to determine, previous to experiment, which plate will be poſitive, and which negative. This effect depends on a variety of circumſtances: according to Mr. Bennet, on the nature of the connexion

* Read on Spontaneous Electricity, p. 29.

formed between the plates and adjoining ſubſtances; and, according to Mr. Read, on the ſtate of the atmoſphere in which the doubler is uſed.

In the experiments of both on this ſubject, we meet with acknowledged anamolies. Indeed, the experience of ſuch diſappointments, and of the embarraſments attending them, is the common fate of thoſe who inveſtigate the changeable electricities of ſurfaces. This is particularly the caſe where the expreſſions of electricity are feeble; nor are we to be ſurprized, that a ſmall effect ſhould be ſubject to variation when it is expoſed to the influence of the air that is perpetually changing, and of all the

vapours and floating ſubſtances which it is perpetually collecting and depoſiting.

You witneſſed the irregularities I allude to, in our experiments on the electrophorus; when, after twenty repetitions ſucceeding each other, and ſhewing that its ſingular appearances depended on the previous contact of the * *upper or lower ſurface* firſt, a ſudden change took place, and as many ſubſequent efforts were followed by an uninterrupted ſeries of irregularities.

* Vide p. 172, 173.

FIG. XXVI.

The moveable doubler's mode of operation is, by Mr. Bennet the inventor, ſuppoſed to be the following:

He firſt conſiders the fluid as exiſting in C and B; the latter of which plates is neceſſarily in a ſtate oppoſite to that of the former.--- When B, thus charged, comes in its rotation oppoſite to A, the electricity it produces in A is different from its own, and conſequently the ſame with that of C, at the moment in which B a ſecond time is oppoſed to C. A metallic wire connects C and A, and the power of two negatives acts upon B, and

doubles the intenſity of its electricity. By each ſeparate revolution, this doubling proceſs is repeated, ſo that the accumulation, collected by the ſucceſſive rotations, is the amount of a geometric ſeries, in which the ſum of twelve terms, or the effect of twelve revolutions of the handle, is upwards of a thouſand times greater than the firſt term, or the effect of the firſt revolution.

If this theory be true, the firſt production of electricity muſt be infinitely ſmall; for, after ten revolutions, the electricity of the beſt doubler will ſcarcely affect the moſt ſenſible doubler. But, here again, Mr. Bennet has recourſe to a principle which I have al-

ready controverted. He aſſumes the poſſibility that a negative can act independently of its correſpondent poſitive, and that a negative of one degree of intenſity ſhould produce a poſitive of a higher intenſity than that of its own electricity. A, C, and B, are all charged equally high; but A and C together make B higher.

I do not feel the neceſſity, in the preſent inſtance, of introducing a principle which I think, and have endeavoured to prove, is directly oppoſed by many well known facts.

If the plate of air between B and C be conſidered as analogous to the varniſh between the ſcudo

and the copper plate, the inſtrument will then be no more than a common electrophorus, and every previous condition for the charging of the one will be found neceſſary for the charging of the other.--- Both require the ſame double communication between their oppoſite ſurfaces and the ground, and both have their electricities increaſed when they are brought near each other, *already charged*. Beſides, the oppoſite electricities of the plates are perfectly analogous to thoſe of the ſcudo and the copper plate, and it is evident that there muſt be, with every revolution of the doubler, that increaſed excitation which is produced by conveying the ſcudo of one electrophorus charged, to the ſurface of

another electrophorus uncharged: by this means the electricity of both come to the maximum of their intenſity.

When I entered upon Mr. Bennet's explanation of the doubler, I conſidered the electricity as *already generated.* One queſtion, therefore, ſtill remains to be anſwered: Whence does that fluid proceed, which, after one revolution, is found in the plates?

Mr. Read maintains that it comes from the ſurrounding air.——He grounds this hypotheſis on the ſimilarity which he always found to take place between the electricity of the doubler, and that of the atmoſphere. I cannot reconcile

Mr. Read's opinion with ſeveral of Mr. Bennet's experiments, in which he evidently proves that circumſtances, whoſe operation can have no connection with the ſtate of the ſurrounding atmoſphere, change all the appearances produced by the inſtrument. The whole air of a room cannot ſurely be affected by ſo ſmall a difference as that of touching the plate with a piece of lead or a piece of iron. But a total change in the electricities of the plates was found by Mr. Bennet to be the conſequence of ſuch a difference. I would not, however, deny that the cauſe aſſigned by Mr. Read may not have ſome effect; for we well know that the nature of communicated electricity materially af-

fects the appearances of the electrophorus.

Mr. Bennet conſiders "*the approach of the two parallel plates as adequate to the electricity in queſtion.*" You will remember, that throughout the whole of theſe Lectures, I have availed myſelf of this principle, viz. that contact muſt alter the capacity of bodies, and of courſe produce a ſeparation of their conſtituent parts. But however diſpoſed I may be to admit Mr. Bennet's theory as favourable to my own ideas, I am yet inclined to doubt the operation of it, where ſuch a diſtance ſeparates the two bodies, as that neceſſary to the operation of the *doubler*. Beſides, the motion of the plate through

the air, and the friction of the axis in the collar of the inſtrument, are very probable ſources of excitation.

If the blowing of a little duſt from a pair of bellows will produce fluid enough to ſeparate the gold leaf ſtrips, why may not the perpetual percuſſion of the plate againſt the air, and the heterogenous particles with which it is loaded, produce a ſimilar effect?

If marble and metal, by ſimple contact, excite electricity, why ſhould not the rapid movement of metal in wood, or of metal in metal, be attended with the ſame conſequences?

Do not conſider me as aſſerting that Mr. Bennet is not right; for I know not at what diſtance that attractive influence ceaſes to act, upon whoſe energy the ſeparation of the fluid depends: but I muſt feel the preceding objections, till removed by the evidence of experiment.

ON ELECTRICAL LIGHT.

I now proceed to the diſcuſſion of certain appearances which are common to all our preceding experiments. From a regard to their varieties and importance, I have reſerved them as a ſeparate object of attention. Indeed, I conſider the electric fluid and light to be diſtinct bodies; and I conſequently

thought that you would be more able to comprehend the ſimple operations of the former, if they were not blended with the effects reſulting from its connection with the latter. In the Philoſophical Tranſactions, I have arranged all the peculiarities of electrical light under ſix general heads. Theſe I ſhall now repeat to you.

I. *There is no fluid or ſolid body in its paſſage through which the electric fluid may not be made luminous.*

In water, ſpirits, oil, animal fluid of all kinds, the diſcharge of a Leyden phial, of almoſt any ſize, will appear very ſplendid, provided we take care to place them in the

circuit, ſo that the fluid may not paſs through too great a quantity of them. My general method is, to place the fluid, on which I mean to make the experiment, in a tube three-fourths of an inch in diameter, and four inches long. I ſtop up the orifices of the tubes with two corks, through which I puſh two pointed wires, ſo that the points may approach within one-eighth of an inch of each other. The fluid, in paſſing through the interval which ſeparates the wires, is always luminous, if a force be uſed ſufficiently ſtrong. I ſhould obſerve, that the glaſs tube always breaks, when this experiment ſucceeds. To make the paſſage of the fluid luminous in the acids, they muſt be placed in capillary

tubes, and two wires inſerted as in the preceding experiment, whoſe points ſhall be very near each other.

It is a well known fact, that the diſcharge of a ſmall Leyden phial, in paſſing a ſtrip of gold, ſilver, or Dutch metal leaf, will appear very luminous. By conveying the contents of a jar, meaſuring two gallons, over a ſtrip of gold leaf, one-eighth of an inch in diameter, and a yard long, I have frequently given the whole a dazzling brightneſs. I cannot ſay, that a much greater length might not have been made very ſplendid, nor have I yet determined to what length the contents of a battery might be

made luminous in this manner.--- We may give this experiment a curious diverſity, by laying the gold or ſilver leaf on a piece of glaſs, and then placing the glaſs in water; for the whole length of the metallic leaf will appear moſt brilliantly luminous, by expoſing it, thus circumſtanced, to the exploſion of a battery.

II. *The difficulty of making any quantity of the electrical fluid luminous in any body, increaſes as the conducting power of that* body *increaſes.*

Experiment 1. In order to make the contents of a jar luminous in *boiling* water, a much higher charge is neceſſary than would be ſufficient to make it luminous in cold

water, which is univerſally allowed to be the worſt conductor.

Exp. 2. I have various reaſons for believing the acids to be very good conductors. If, therefore, into a tube filled with water, and circumſtanced as I have deſcribed, a few drops of either of the mineral acids be poured, it will be almoſt impoſſible to make the fluid luminous in its paſſage through the tube.

Exp. 3. If a ſtring, whoſe diameter is one-eighth of an inch, and whoſe length is ſix or eight inches, be moiſtened with water, the contents of a jar will paſs thro' it luminouſly; but no ſuch ap-

pearance can be produced by the paſſage of any charge, provided the ſame ſtring be moiſtened with one of the mineral acids.

To the preceding inſtance we may add the various inſtances of metals which will conduct the electric fluid without any appearance of light, in circumſtances the ſame with thoſe in which an equal charge would have appeared luminous in paſſing through other bodies whoſe conducting power is leſs.

III. *The eaſe with which the electric fluid is rendered luminous in any particular body, is increaſed by increaſing the rarity of that body.* The appearance of a ſpark, or of the diſcharge of a Leyden phial,

in rarefied air, is well known. But we need not reſt the truth of the preceding obſervation on the ſeveral varieties of this fact; ſimilar phœnomena attend the rarefaction of æther, of ſpirits of wine and of water.

Exp. 4. Into the orifice of a tube, forty-eight inches long and two-thirds of an inch in diameter, I cemented an iron ball, ſo as to bear the weight which preſſed upon it when I filled the tube with quickſilver, leaving only an interval at the open end, which contained a few drops of water.--- Having inverted the tube, and plunged the open end of it into a baſon of mercury, the mercury in the tube ſtood nearly half an

inch lower than it did in a barometer at the ſame inſtant, owing to the vapour which was formed by the water; but through this rarified water the electrical ſpark paſſed as luminouſly as it does thro' air equally rarefied.

Exp. 5. If, inſtead of water, a few drops of ſpirits of wine are placed on the ſurface of the mercury, phœnomena, ſimilar to thoſe of the preceding experiment, will be diſcovered, with this difference only, that as the vapour in this caſe is more denſe, the electrical ſpark, in its paſſage through it, is not quite ſo luminous as it is in the vapour of water.

Exp. 6. Good æther, ſubſtituted

in the room of ſpirits of wine, will preſs down the mercury ſo low as the height of ſixteen or ſeventeen inches. The electrical fluid, in paſſing through this vapour (unleſs the force be very great indeed) is ſcarcely luminous: but if the preſſure on the ſurface of the mercury in the baſon be gradually leſſened by the aid of an air pump, the vapour will become more and more rare, and the electric ſpark, in paſſing thro' it, more and more luminous.

Exp. 7. I could not diſcover that any vapour eſcaped from the mineral acids, when expoſed in vacuo. To give them, therefore, greater rarety or tenuity, I found different methods neceſſary. With

a fine camel hair pencil, dipped in the vitriolic, the nitrous, or the marine acid, I drew upon a piece of glaſs a line about one-eighth of an inch broad. In ſome inſtances I extended this line to the length of twenty-ſeven inches, and found that the contents of an electrical battery, conſiſting of ten pint phials coated, would paſs over the whole length of this line with the greateſt brilliancy. If, by widening the line, or by laying on a drop of the acid, its quantity was increaſed in any particular part, the charge, in paſſing through that part, never appeared luminous. Water or ſpirits of wine, circumſtanced ſimilarly to the acids in the preceding experiment, were attended with ſimilar but not equal effects, be-

cauſe, in conſequence of the inferiority of their conducting power, it was neceſſary to make the line, through which the charge paſſed, conſiderably ſhorter.

IV. *The brilliancy or ſplendour of the electric fluid, in its paſſage through any body, is always increaſed by leſſening the dimenſions of that body.* I would explain my meaning by ſaying, that a ſpark, or the diſcharge of a battery, which we might ſuppoſe equal to a ſphere one-fourth of an inch in diameter, would appear much more brilliant, if the ſame quantity of the fluid were compreſſed into a ſphere one-eighth of an inch in diameter. This obſervation is the obvious conſequence of many known facts. If

the machine be large enough to afford a ſpark, whoſe length is nine or ten inches, this ſpark may be ſeen ſometimes forming itſelf into a bruſh, in which ſtate it occupies more room, but appears very faintly luminous. At other times the ſame ſpark may be ſeen dividing itſelf into a variety of ramifications, which ſhoot into the ſurrounding air. In this caſe likewiſe, the fluid is diffuſed over a large ſurface, and, in proportion to the extent of that ſurface, ſo is the faintneſs of the appearance. A ſpark which, in the open air, cannot exceed one-fourth of an inch in diameter, will appear to fill the whole of an exhauſted receiver, four inches wide and eight inches long; but in the former caſe it is brilliant,

and in the latter it grows fainter and fainter, as the ſize of the receiver increaſes. To prove the obſervation, which I think may be juſtified by the preceding facts, I made the following experiments.

Exp. 8. To an inſulated ball, four inches in diameter, I fixed a ſilver thread about four yards long. —— This thread, at the end which was remoteſt from the ball, was fixed to another inſulated ſubſtance. I brought the ball within the ſtriking diſtance of my conductor, and the ſpark, in paſſing from the conductor to the ball, appeared very brilliant; but the whole length of the ſilver thread appeared faintly luminous at the ſame inſtant. In other words, when

the ſpark was confined within the dimenſions of a ſphere one-eighth of an inch in diameter, it was bright; but when diffuſed over the ſurface of air which received it from the thread, its light became ſo faint, as to be ſeen only in a dark room. If I leſſened the ſurface of air which received the ſpark, by ſhortening the thread, I never failed to increaſe the brightneſs of the appearance.

Exp. 9. To prove that the faintneſs of the electric light in vacuo depends on the enlarged dimenſions of the ſpace through which it is diffuſed, we have nothing more to do, than to introduce two pointed wires into the vacuum, ſo that the fluid may paſs from the

point of the one to the point of the other, when the diſtance between them was not more than one-tenth of an inch. In this caſe we ſhall find a brilliancy as great as in the open air.

Exp. 10. Into a torricellian vacuum, thirty-ſix inches in length, I conveyed as much air as would have filled two inches only of the exhauſted tube, if it were inverted in water. This quantity of air afforded reſiſtance enough to condenſe the fluid as it paſſed through the tube, into a ſpark thirty-eight inches in length. The brilliancy of the ſpark in condenſed air, in water, and in all ſubſtances thro' which it paſſes with difficulty, depends on principles ſimilar to thoſe

which account for the preceding facts.

V. *In the appearances of electricity, as well as in thoſe of* burning bodies, *there are caſes in which all the rays of light do not eſcape. The moſt refrangible are thoſe which eſcape firſt or moſt eaſily.* The electrical bruſh is always of a purple or bluiſh hue. If you convey a ſpark through a torricellian vacuum, made without boiling the mercury in the tube, the bruſh will diſplay the indigo rays. The ſpark, however, may be weakened and divided, even in the open air, ſo as to yield the moſt refrangible rays only.

Exp. 11. To an inſulated me-

tallic ball, four inches in diameter, I fixed a wire a foot and a half long. This wire terminated in four ramifications, each of which was fixed to a metallic ball half an inch in diameter, and placed at an equal diſtance from a metallic plate, which communicated by metallic conductors with the ground. A powerful ſpark, after falling on the large ball at one extremity of the wire, was divided in its paſſage from the four ſmall balls to the metallic plate. When I examined this diviſion of the fluid in a dark room, I diſcovered ſome little ramifications, which yielded the indigo rays only: indeed, at the edge of all weak ſparks, the ſame purple appearance may be diſcovered. We may likewiſe ob-

ſerve, that the nearer we approach the centre of the ſpark, the greater is the brilliancy of its colour. But I would now wiſh to ſhew,

VI. *That the influence of different media on electrical light, is analogous to their influence on ſolar light, and will help us to account for ſome very ſingular appearances.*

Exp. 12. Let a pointed wire, having a metallic ball fixed to one of its extremities, be forced obliquely into a piece of wood, ſo as to make a ſmall angle with the ſurface of the wood, and to extend its point one-eighth of an inch below the ſurface; let another pointed wire, which communicates

with the ground, be forced in the ſame manner into the ſame wood, ſo that its point likewiſe may be about one-eighth of an inch below the ſurface, and about two inches diſtant from the point of the firſt wire; let the wood be inſulated, and a ſtrong ſpark, which ſtrikes on the metallic ball, will force its paſſage through that interval of wood which lies between the points, and appears as red as blood. To prove that this appearance depends on the wood's abſorption of all the rays, but the red, I would obſerve that the greater is the depth of the points below the ſurface, the leſs mixed are the red rays. I have been able ſometimes, by increaſing or diminiſhing the depth of the

points, to give the ſpark the following ſucceſſion of colours.

When they were deepeſt below the ſurface, the red only came to the eye through a priſm. When they were raiſed a little nearer the ſurface, the red and orange appeared; when nearer ſtill, the yellow, and ſo on, till, by making the ſpark paſs through the wood very near its ſurface, all the rays were at length able to reach the eye. If the points be only one-eighth of an inch below the ſurface of ſoft deal wood, the red, the orange, and the yellow rays, will appear as the ſparks paſs through it: but when the points are at an equal depth in a harder piece of wood (ſuch as box) the

yellow, and perhaps the orange, will diſappear.

As a farther proof that the phœnomena, I am deſcribing, are owing to the interpoſition of the wood, as a medium which abſorbs ſome of the rays, and ſuffers others to eſcape, it may be obſerved that when the ſpark ſtrikes very brilliantly on one ſide of the piece of deal, on the other ſide it will appear very red. In like manner, a red appearance may be given to a ſpark which ſtrikes brilliantly over the inſide of a tube, merely by ſpreading ſome pitch very thinly over the outſide of the ſame tube.

Exp. 13. I will now give another

fact, whoſe ſingularities depend very much on the influence of the medium, through which the electrical light is made to paſs. If into a torricellian vacuum, of any length, a few drops of æther are conveyed, and both ends of the vacuum are ſtopped up with metallic conductors, ſo that a ſpark may paſs through it, the ſpark in its paſſage will aſſume the following appearances:

When the eye is perfectly cloſe to the tube, the ſpark will appear perfectly white. If the eye be removed to the diſtance of two yards, it will appear green; but at the diſtance of ſix or ſeven yards, the colour of the ſpark will be reddiſh. Theſe changes evi-

dently depend on the quantity of medium through which the light paſſes, and the red light more particularly, which we ſee at the greateſt diſtance from the tube, is accounted for on the ſame principle as the red light of a diſtant candle or a beclouded ſun.

Exp. 14. Dr. Prieſtley, long ago, obſerved the red appearance of the ſpark, when paſſing through inflammable air. But this appearance is very much diverſified by the quantity of the medium thro' which you look at the ſpark.—When the eye is at a very conſiderable diſtance, the red comes to it unmixed; but if the eye be placed cloſe to the tube, the ſpark appears white and brilliant. In

confirmation, however, of ſome of my concluſions, I would obſerve, that by increaſing the quantity of electric fluid which is conveyed through any portion of inflammable air, or by condenſing that air, the ſpark may be entirely deprived of its red appearance, and made perfectly brilliant. I have only to add, that all weak exploſions and ſparks, when viewed at a certain diſtance, bear a reddiſh hue. Such are the exploſions which paſs thro' water, ſpirits of wine, or any bad conductor, when confined in a tube, whoſe diameter is not more than one inch. The reaſon of theſe appearances ſeems to be, that the weaker the ſpark or exploſion is, the leſs is the light which eſcapes, and the more viſible the

effect of any medium which has a power to abſorb ſome of that light.

The preceding experiments and obſervations were the conſequence of directing my attention to the analogy ſubſiſting between electric light and that of bodies in a ſtate of combuſtion. In a few queries (expreſſed at the end of the paper which I have already alluded to) I have conjectured that the ſame theory may account for both. In the different ſtages of combuſtion I have endeavoured to ſhew that the different rays are emitted in proportion to the degree of decompoſition that takes place in the burning body; that in the naſcent ſtate of combuſtion the violet rays

eſcape firſt, then the next in the order of refrangibility ſucceeds, and ſo on, till the body at length retains none but the red rays; or that, in their laſt ſtate of combuſtion, all bodies muſt, agreeably to the theory as well as to obſervation, be of a red colour. On my brief conjectures, as expreſſed in the Tranſactions, I will now beg leave to amplify.

1ſt, I have aſked this queſtion, whether the attractive force which unites the conſtituent parts of different bodies, muſt not be altered by increaſing or diminiſhing the quantity of any particular conſtituent which enters into the body? I will thus explain my meaning: ſuppoſe the body, D, to be a com-

pound, consisting of three different ingredients, which I call A, B, and C; suppose this compound to retain the union of its parts unaltered, while A consists of fifty particles, B of twenty, and C of ten; while D remains in this undivided state, suppose an exterior force, E, to have an affinity with or to exercise an attractive force upon the particles of the ingredient A, it is evident, from the continued union of D's several parts, that E is not adequate to the separation of those parts, while the quantities of A and B remain unaltered. But let us suppose the reduction of B to ten, it is then obvious that there will be a less force to act upon the ingredients A and B, and that the exterior will then be likely to take

ſome of thoſe ingredients to itſelf. Again, let us ſuppoſe that A is increaſed to one hundred, in that caſe a ſeparation muſt take place, for the addition will exerciſe an attractive force upon the particles which are ſimilar to themſelves, or upon the fifty particles which already exiſt in A. The union between A and the two other ingredients will be thus leſſened, and conſequently the ſame effects will reſult from the operation of an exterior influence, as in the preceding inſtance.

Facts without number ſeem to ſhew the actual exiſtence of what I have now ſtated as undeniable poſſibilities. All the decompoſitions produced by adding heat to

ſuch combuſtibles as are at the time expoſed to the influence of the atmoſphere, may (in my opinion) be eaſily accounted for by an application of the laſt caſe which I have ſtated. In like manner, many of the effects of cold may be traced to the cauſes deſcribed in the firſt of the two caſes. As, however, any reaſoning derived from the corporeal nature of heat will be rejected by thoſe who aſcribe heat to a ſomething unknown, I will ſtate to you ſome other inſtances.

Glaſs is a compound of two bodies, which we call an alkali and an earth. This compound is not at all affected by either of the mineral acids, while the quantity of the

alkali does not exceed one-third of that of the earth, increaſe the quantity of the alkali to two-thirds, and then unite an acid, and you will find all the alkali immediately ſeparated, and pure ſilicious earth depoſited.

Common ſulphur is not operated upon by the air; but if you increaſe ſome of the conſtituent acid, the air immediately prevails, and attaches ſome of the body to itſelf. On the Stahlian principles, this inſtance will apply to the ſecond, but, agreeably to the theory of Levoiſier, it applies to the firſt of the two caſes.

But I proceed to the ſecond queſtion which I aſked, and that

is, provided the language I have juſt now uſed be admitted, whether the caſes I have ſtated may be applied to the decompoſitions produced by the electric fluid. Facts without number prove, that when the fluid is added to, or taken away from a body in a certain proportion, a ſeparation of parts in that body is the certain conſequence. The charge of a battery will calcine metals, will volatilize oils, will produce air from water, ſpirits of wine, &c. will break glaſs, and, in ſhort, produce almoſt every effect which is cauſed by other modes of decompoſition.

Allowing the truth of what I have now ſaid, we may anſwer the third queſtion I propoſed with,

out difficulty, and we thereby ſhall come immediately to the elucidation of the fact I would wiſh to explain.

If light be a conſtituent part of bodies, and if an addition of the electric fluid cauſes a ſeparation of parts, muſt not the addition of it, in a certain degree, be always attended with light? I anſwer, that ſeveral of the general obſervations I have made, will juſtify ſuch a concluſion.

1ſt, The addition of the electric fluid, to any body whatever, is attended with a ſeparation of light. 2d, The rarer any body is, the eaſier is the paſſage of the fluid thro' it made luminous; that is,

agreeably to the theory, the proportion which the addition bears to the conſtituent parts, is thus conſiderably increaſed, and, conſequently, the production of the effect is facilitated. ——— Thus, ſuppoſe D to be compounded of A=10. and B=10. the addition of 100 to the body thus proportioned, would be attended with greater effects than if A=100. and B=100. A teſtimony, equal to that of the third obſervation, is given to my theory by that of the fourth obſervation, in which I have ſaid, that the brilliancy or ſplendour of the electric ſpark, in its paſſage through any body, is always increaſed by diminiſhing the dimenſions of the body. My laſt queſtion, relating to the electric light, was the following:

In the diminution or alteration of that attractive force, on which depends the conſtitution of bodies, may there be not ſome gradation which will cauſe the eſcape of ſome rays ſooner than others? (i. e.) while a ſmall addition to the conſtituent electric fluid, in any body, is able to ſeparate from their baſis one ſpecies of rays, will not a greater addition cauſe the releaſe of more rays? a greater ſtill, the releaſe of three ſorts of rays? and ſo on, till the addition be adequate to the ſeparation of all the rays, or to the appearance of a brilliant white ſpark?

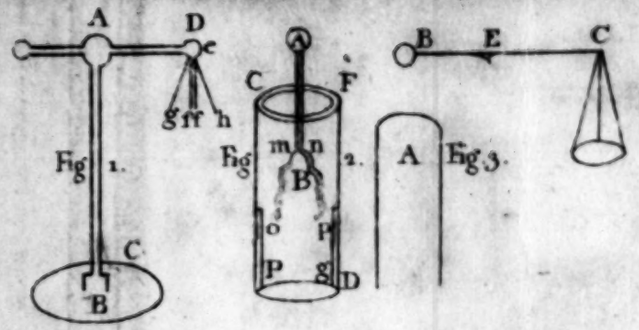
The experiments, which I have enumerated, ſeem to favor ſtrongly this part of the theory, and to

ſhew, at the ſame time, that the rays which are firſt emitted are the indigo, and the ſpark becomes more and more mixed, as you increaſe the addition of the fluid, ſo as to approximate a perfect decompoſition. But it is time I ſhould now proceed to another very extenſive part of theſe Lectures, in which, as well as in the preceding, I have no other guide than my own experience, and the concluſions which it has led me to form and to adopt.

BRITISH
6 JY 74
MUSEUM

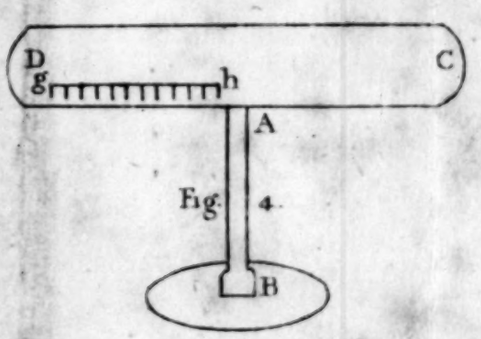
28101

F248


A
D
g
f
h
Fig 1.
C
B

C
F
m
n
Fig 2.
B
o
p
P
P
g
D

B
E
C
A
Fig 3.


D
g
h
C
A
Fig. 4.
B

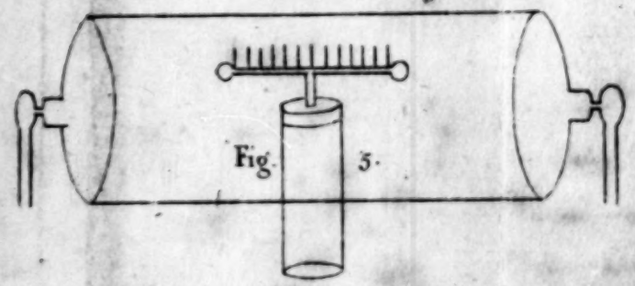
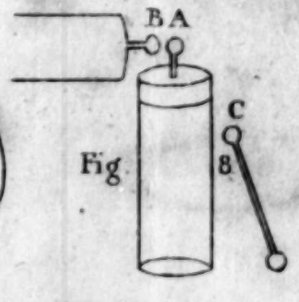


Fig. 5.

Fig 6.

A
Fig. 7.
B


B
A
C
Fig 8.

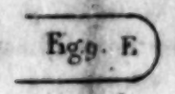
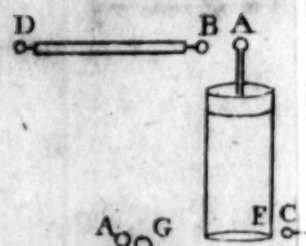


Fig 9. E


D
B
A
F
C
C
D

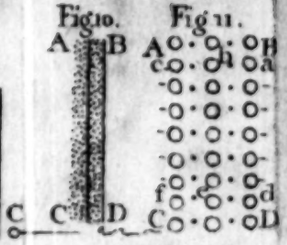
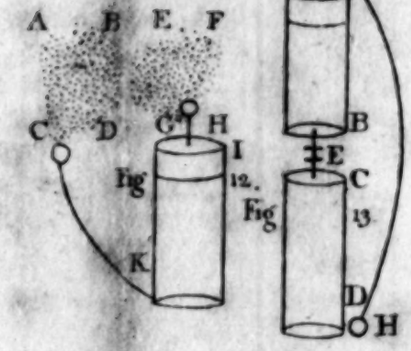
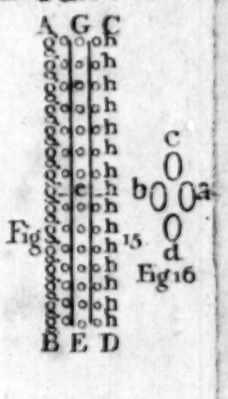


Fig 10.
A
B
C
D

Fig 11.
A
B
C
D


A
B
E
F
C
D
G
H
I
Fig 12.
K
Fig
C
13
D
H

A
C
B
Fig 14


A
G
C
B
E
Fig
15
Fig 16

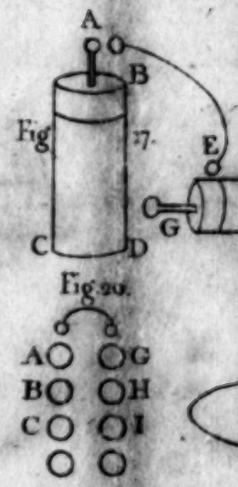
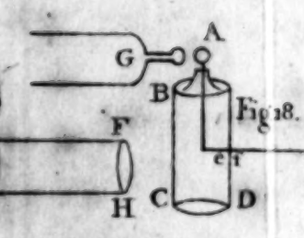

A
B
Fig 17.
C
D
E
G
F
H

Fig 20.
A
G
B
H
C
I

A
Fig 21
B


G
A
B
Fig 18.
C
D

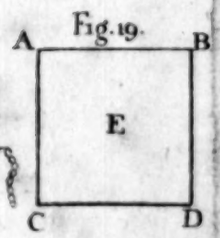
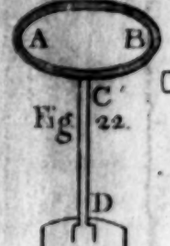
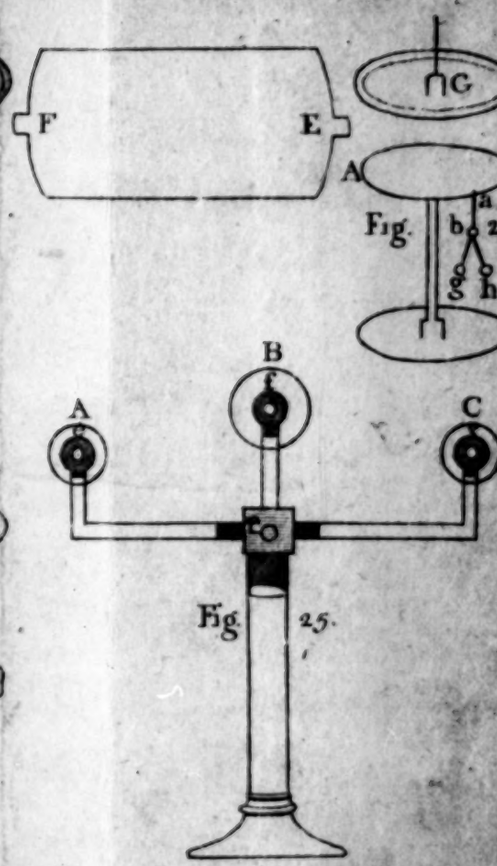


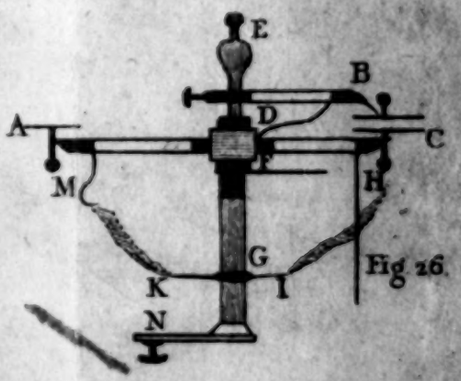
Fig. 19.
A
B
E
C
D


A
B
C
Fig 22.
D

A
Fig 24.
B

C


F
E
G
A
B
Fig. 23.
a
b
g
h
B
A
C
Fig. 25.


E
B
A
D
C
M
F
H
G
K
I
N
Fig 26.